"FOUNDATIONS OF NATURE STUDY" SERIES

ANIMAL STUDIES

BY
JAMES A. TODD

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"*FOUNDATIONS OF NATURE STUDY*" *SERIES*

ANIMAL STUDIES

Foundations of Nature Study Series

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ANIMAL STUDIES

BY

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GENERAL PREFACE

There is little disagreement about the value of Nature Study properly conducted. In addition to providing a knowledge of facts (and that must not be despised), the subject is mainly useful when it stimulates the natural curiosity of the child, leads him to look at things for himself because he is interested, and to discuss them with his neighbours and his teachers. The function of the teacher is to guide his energies, to help him to interpret what he sees, and to lead him on to further inquiries. The reaction against book-knowledge is of old standing. Even Ecclesiastes said in his time: "Of making many books there is no end; and much study is a weariness of the flesh." Nature Study for the child is not a matter of books. The teacher should have some knowledge of many sciences, and it is the selection of the minimum which is all-important. Many teachers confess to a feeling of dread when the Nature Study lesson approaches: the questions which may arise are so manifold, their own knowledge so inadequate. Too much attention has hitherto been paid to the minutiae of certain sections of Natural Science. Safety lies in the broad lines. The "Foundations of Nature Study" Series is an attempt to make these lines plain. It is the outcome of lectures given to students of the Edinburgh Provincial Training College, and is published mainly to obviate the waste of time that note-taking involves, but also with the hope that, whatever its imperfections, it may be useful to teachers generally.

My thanks are due to my colleagues, Mr J. H. Gray, M.A., B.Sc., and Miss I. M. King, B.Sc., for their invaluable assistance in the preparation of the lectures; to my wife, for reading the proofs and assisting in various ways; and to the many writers whose books have been helpful.

J. A. T.

EDINBURGH, 1924.

NOTE TO *ANIMAL STUDIES*

Figures Nos. 20-31 inclusive (No. 29 excepted) have been drawn by my friend, A. R. BEE, M.A., Edinburgh, whose valuable assistance I gratefully acknowledge.

J. A. T.

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CHAPTER I

INTRODUCTION : UNICELLULAR ANIMALS AND SPONGES

Introduction.—*Biology* (Gk. *bios.*, life) is the study of living things, both plant and animal. This volume deals with the zoological (Gk. *zoon*, an animal) aspect of the subject, and is an attempt to give the student a general survey of the Animal Kingdom, with the special aims of demonstrating the evolution of the highest animals from simple beginnings ; of providing a background which will give definition to further studies in the subject ; and of emphasising in all cases the correlation between living organisms and their environment and the responses called forth by varying conditions.

In the simplest forms of life the distinction between plant and animal is not always clear. This in itself is a point in favour of common descent. It is believed that life started in the water, possibly when the whole surface of the earth was sea ; that the primary organisms were minute single cells : that eventually some of these combined to form colonies ; that gradually differentiation in the function of groups of cells began and so produced in time various complex forms ; that land came by upheavals of the earth's crust due to contraction and that some of these marine forms took to seashore life (*i.e.* half in and half out of the water) ; and that, of these, some, in process of time, moved landwards and remained as permanently terrestrial animals.

Doctrine
Evolutio

The various changes in the structure and mode of life of animals have been brought about largely in response to the increasing difficulty, as the number of organisms increased, of obtaining a sufficient food supply, this being the real "struggle for existence." Because of certain differences in individuals of the same group some became more fitted for the struggle and survived at the expense of their less fortunate fellows. Thus animals which became able to live out of water, for even a short time, had an advantage over the others, and as their numbers increased, those able for the longest period to remain out of water had the best chance.

It must not be thought that the higher animals have descended directly from the lower forms as we know them at present. All have had the same common ancestors belonging to the very early stages, but the line of evolution has branched, and branched again, some lines leading onwards and making for improvement, while some led to disaster and final extinction.

It should be noted that every living organism begins as a single cell, usually the product of the union of single cells from the two parents. Development in the embryonic period, of all vertebrate animals at least, follows pretty much the same lines, so that at certain stages the embryos of a Bird, of a Reptile, of a Rabbit are almost identical. These facts have given rise to the theory of *Recapitulation*, capitulation i.e. that the individual in the course of its development repeats the evolutionary history of the race or, as it has been well put, "climbs its own genealogical tree." Certainly all start at the protozoan stage, *i.e.* are one-celled organisms.

Classification of animals.—Just as plants show a gradation from the very simple unicellular types to the most highly organised amongst the flowering plants, so in the Animal Kingdom a similar ascending plane of genus. complexity is apparent. Groups are formed of animals which agree in general structure and physiological characters, without regard to mode of life, which may vary enormously amongst the individual species which make up the group. Thus Whales and Porpoises, which are fish-like in appearance and general habit, belong not to the Fishes at all, but, because they are air-breathers, suckle their young with milk, and have the same sort of internal structure, are placed amongst the Mammals, the group which contains the highest animals.

Animals may be divided into three main groups : Phyla.

1. Unicellular animals, the **Protozoa**.

2. Animals with bodies but no backbones, the **Invertebrates**.

3. Animals with backbones, the **Vertebrates**.

Between the Protozoa and the others there is a great gap, though some of the unicellular types associate themselves together in a colonial way, thus foreshadowing the aggregation of cells found in the multicellular animal, where groups of cells, similar in origin, adopt specialised functions involving a division of labour, this differentiation being however, in the simplest types, of small amount.

Another large gap occurs between the Invertebrates and the Vertebrates. Here, however, intermediate types are known, which exhibit characters of both groups, and so the gap is more or less bridged.

PROTOZOA

1st phylum.

These are the simplest animals, and each consists of a single cell, usually, but not always, surrounded by a cell wall. Within is a minute drop of protoplasm, or living substance, in which may be seen a denser portion, the *nucleus*, and one or more clear round globules, the *vacuoles*. The nucleus is the dynamic centre which seems to control the activities of the cell, while the vacuoles appear to be concerned with the elimination of waste products. They increase in size and finally burst to the exterior, thus providing a simple process of excretion.

otozoa. – (1) unicellular.
(2) mycroscopic.

Amoeba, the **Proteus Animalcule** (Gk. *Proteus*, a marine deity able to assume different shapes), Fig. 1, is the simplest type of the Protozoa. It may be found in mud at the edges of ponds, etc., is microscopic in size, and somewhat difficult to see on account of its transparency. It shows an irregular outline which is constantly changing. There is no cell wall, and the animal moves by thrusting out a finger-like process and then gliding or flowing after it. Within the cell may be seen the nucleus and several vacuoles.

oeba Proteus :-(1) lives in damp situations - at the edge of ponds on very damp wood: where ai is very moist.
) it eats small pieces organic material - stems ggs.
it gets its od by moving out in search of it.
)t moves by rawling.
It recognises its od by ception the nature touch imulus.

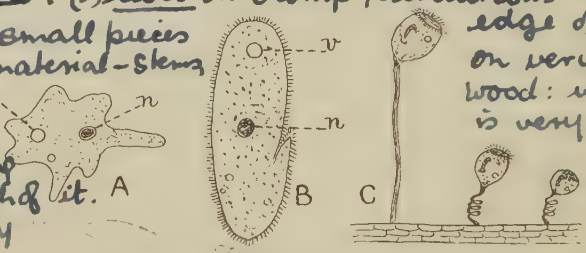

FIG. 1.—Protozoa. A, Amoeba; B, Paramoecium; C, Vorticella
n = nucleus; v = vacuole

It feeds by engulfing particles at any point of its surface, digests the material and gets rid of waste matter by means of the vacuoles, which may be seen to grow larger until, when a limit is reached, they suddenly disappear. The animal grows in size and ultimately divides into two parts, the nucleus also dividing, one half going to each of the new cells. Sometimes a process of simple conjugation may be observed. Two individuals come together and, apparently, an exchange of nuclear elements takes place. Thereafter the animals separate.

When unfavourable conditions arise, *e.g.* drought, the animal becomes globular and produces a tough cell wall. When normal times return the cell wall is ruptured and Amoeba sallies forth. During this resting stage the animal is said to *encyst*.

Allied to Amoeba are the **Phagocytes** or white corpuscles of the blood, often called *Amoebocytes*. Their function seems to be to wander through the blood and tissues and to attack foreign bodies such as disease germs, which they engulf and digest. Other allies are the **Foraminifera**, which give rise to the oozes found on the floors of the oceans and out of which chalk has been formed. They have gone a stage further than Amoeba and are surrounded by calcareous shells perforated by innumerable pores or small holes (L. *foramen*, a hole) through which the threads of protoplasm may be protruded or withdrawn.

Other types of Protozoa.—**Paramoecium**, the **Slipper Animalcule** (Fig. 1), is more highly organised. It too may be found in mud or by soaking some fragments of hay or other vegetable matter in water. The animals may have been encysted, but in a few days resume activity and increase enormously in number.

Here the animal is bounded by a more definite cell wall, and shows a definite "mouth" or place at which ingestion takes place. Round the exterior are minute lash-like cilia (L. *cilium*, an eyelash) which waft food particles towards the mouth or serve as organs of locomotion by which the animal is able to swim rapidly through the water. Vacuoles are formed and these seem to reach the exterior at a definite region behind the mouth.

Life history.—When the limit of growth is reached the animal splits obliquely into two, a process of simple fission, one half of the nucleus going to each daughter cell. The process of conjugation also takes place and has been carefully followed. Two individuals fuse for a time, an exchange of nuclear elements takes place, whereupon the individuals separate, the newly formed nuclei apparently containing hereditary elements derived from the two sources.

Sexual
Reproduct

Experiments have shown that if this process of conjugation is prevented the animals ultimately lose in vigour, whereas the conjugation with other individuals appears to lead to invigoration. This process exhibits the essentials of the sexual reproduction of plants and animals in its simplest form and is therefore of great interest.

Vorticella, the **Bell Animalcule** (Fig. 1), is found as a minute white fringe on fresh-water plants. Each individual consists of a bell-shaped body attached to the weed by a contractile stalk. A fringe of cilia round the edge of the bell directs food particles towards a more definite "gullet" than the previous forms possessed. Vacuoles are produced which seem to pass out of this gullet which thus serves for ingestion and excretion. There is a large horseshoe-shaped nucleus.

Reproduction
by Fission
by ~~Sex~~
Conjugation.

Life history.—Reproduction may be by simple fission. Two "bells" are produced by this means on the same stalk. One swims off, attaches itself to a convenient plant and proceeds to grow a new stalk for itself.

Conjugation may also take place. A bell divides into two, and one of the two parts may divide into as many as eight smaller bells. These become detached, swim away, and attach themselves each to a full-sized bell, with which they fuse and by which they are ultimately absorbed.

Like the other types, Vorticella may encyst during unfavourable conditions.

Parasitic Protozoa.—Many of the Protozoa are found as parasites in various organs of other animals. More than thirty are known to be parasitic in the human body, and many are associated with the production of disease, *e.g.* *Amoeba coli*, which produces inflammation of the intestine. Some do not complete their life history in one host, but require two, *e.g.* the malaria parasite, *Plasmodium*, which lives for a time in a species of mosquito and increases there by sexual reproduction. It is then passed by the mosquito into the blood of man, where it increases asexually by a process of division or spore-production.

Sleeping-sickness and Texas fever are other tropical diseases produced by similar Protozoa.

PORIFERA: SPONGES

2nd. Phylum.

✓ **Sponges** (Fig. 2) are sedentary animals, mainly marine, living in deep water, leading a stationary existence fixed to a rock or some seaweed. They are formed of many cells associated together, all, however, being much alike, there being little division of labour. In its simplest form the sponge shows a vase-shaped body composed of two layers of cells. Over the surface are seen many small pores (whence the name Porifera) with here and there larger openings or **oscula**. The cells of the inner layer are provided each with a whip-like thread or **flagellum** (*cf.* the cilia in Protozoa, which are many on one cell). By means of these flagella currents of water are made to pass in at the pores and out at the osculum, nutritive material being absorbed therefrom by the individual cells.

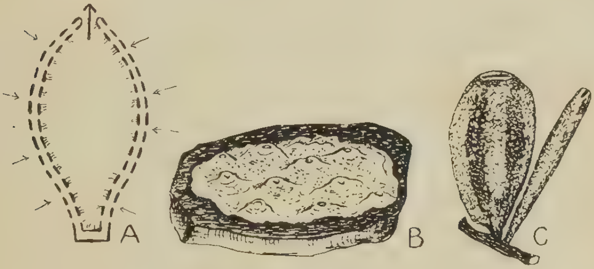

FIG. 2.—Sponges. A, Diagrammatic view of simple Sponge; B, Crumb-of-Bread Sponge; C, Purse Sponge

Life history.—Reproduction may be by budding, the asexual or vegetative method; or by the conjugation of sexual cells which thereby produce a ciliated larva which for a time is free-swimming. This proves the Sponge an animal and not, as was long thought, a plant. The larva

Reproductio
Sexual
(Ciliated
larva
Asexual

ultimately attaches itself to a fixed object and spends the rest of its career as a sedentary Sponge.

General characters. — The cells are supported by a skeleton of horny material, *spongin*, and in addition there may be *spicules* of calcareous or siliceous material, which show a great variety of artistic form.

Some Sponges are found on our own shores, *e.g.* the **Crumb-of-Bread Sponge**, *Halichondria panicea* (Fig. 2), which forms an incrustation, an inch or more across, on the surface of the rock; the **Purse Sponge**, *Grantia compressa* (Fig. 2), which is found attached to seaweeds, is much flattened and bears some resemblance to the article from which it takes its name. In warmer seas, *e.g.* the Mediterranean, large complex forms are found. Most contain spicules as well as the skeleton of spongin. The **Bath Sponge** (*Euspongia*) has no spicules, and it is the skeleton which forms the article of commerce. **Turkey Sponges** are specially fine and soft. Such forms are gathered by divers from the floor of the ocean and spread out on the beach till all the living parts have decayed and been washed away. **Venus' Flower Basket**, a very delicate lace-like skeleton made up of fused siliceous spicules, is one of the most decorative of these sponge remains, while the **Glass Rope Sponge** produces long fibres making a rope-like structure.

1. No definite digestive cavity.

Protozoa.

Amoeba,
Paramecium.
Vorticella.
Sponge.

Amoeba }
e blood – Phagocytes }
corpuscles –
reous shells), Foraminifera }.

moeba :- lives at? on the edges of ponds.
Simplest Protozoa – protoplasm,
sometimes cell-wall, nucleus, vacuoles.
Moves by pushing forth parts, &
following up with the rear.
Food – goes in search of it: small
organic pieces: ingested at any
part: excretion at the vacuoles.
Reproduction by Fission or by Conjugation.

ramaecium:- Distinct mouth: moves through th
water by means of cilia.
Reproduction by Fission
Conjugation.

ticella Attached: mouth: cilia. Gullet.
Mouth used for ingestion & excreti
Reproduction by Fission of cells
Conjugation.

rasitic Protozoa – with one or two hosts.
Reproduction Sexual or
Asexual.

---

ponges :- Marine: sedentary: associated
cells independent of each other.
Pores and oscula.
Flagella make food pass in at the
pores & out at the osculum, food
being taken by the individual cells.
Skeleton of Spongin for support.
Protection by calcareous spicules.
Reproduction by sexual means (ciliate
larva, or by asexual budding.

CHAPTER II

COELENTERATA: STINGING ANIMALS 3rd Phylum

Coelenterata.—The simple types already described have no definite digestive cavity and therein differ from higher animals. In most of the higher types there is a definite digestive or alimentary canal, the gut or enteron, and this lies within another cavity of the body, the **coelom**, or simply the *body cavity*. A moment's consideration of the process of "gutting" fish will make this quite clear. In the Coelenterates, however, there is only one cavity, and as this is body cavity and gut in one, they are called the "coelom-enteron" animals or Coelenterates. Most of the group are wholly, or during part of their existence, sedentary or fixed animals, and are all aquatic, mostly marine. They are provided with **stinging cells**, each of which consists of a coiled tubular thread enclosed in a sac on the outside of which is a short process or trigger. When this is touched the poisonous thread is shot out violently. This provision may be for the purpose of paralysing the minute animals which serve as food or as a protection against attack. Bathers who have been stung by a jellyfish are aware of the irritating nature of the poison. The main types belonging to this group are the **Zoophytes** (Gk. *zoon*, an animal, *phyton*, a plant), *e.g.* *Hydra* and *Obelia*, **Jellyfishes**, **Sea-Anemones** and **Corals**.

✓ **Hydra** (Fig. 3) is a small green animal, $\frac{1}{4}$ to $\frac{1}{2}$ inch in length when extended, but often contracted into spherical form, found on fresh-water plants. The body consists of a two-layered tube fringed at its free end with a series of hollow tentacles. Small organisms, paralysed by the

Diatomes.
Paramoecium.

stinging cells, are wafted by the tentacles into the tube and there digested, waste material being ejected by the same route.

Life history.—Hydra may multiply by a process of simple budding, the buds being set free as new individuals. Reproduction is normally, however, by sexual cells. Swellings of two kinds appear on the body of the Hydra: one, the ovary, produces a single ovum or egg cell, while the other produces spermatozoa each consisting of a small oval head to which is attached a tail by means of which the spermatozoon swims through the water. One ultimately penetrates the ovary and fertilises the egg cell. The latter divides rapidly, becomes enclosed in a tough protecting envelope and falls to the bottom of the water. After a time a young Hydra emerges. Here we have sexual cells of two kinds, male and female, called **gametes** (Gk. *gamos*, marriage). Fertilisation..

edentary
r moving.
can release
elf when
wishes.

receives outside
imuli - translated
to motion -
ervous system
teraction between
ommands +
ction. Ganglia.

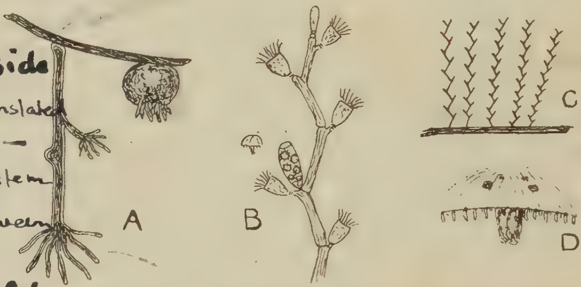

Fig. 3.—Zoophytes. A, Hydra; B, Obelia; C, Obelia (natural size); D, Medusa of Obelia

Obelia (Fig. 3) is a true Zoophyte (Hydra is often excluded from the group) and appears in the form of fine white threads on seaweed. The thread is not an individual but a colony of individuals, each being seated in a little cup attached to the common stem, and each being, in the main, like a minute Hydra.

Life history.—Like Hydra, Obelia produces buds, but these remain attached to the parent and in turn give rise to other buds, thus extending the colony. The sexual reproduction shows new features which characterise many other members of the Coelenterata. Special buds arise which liberate minute swimming bells or **medusae,** just like tiny jellyfishes. Each swims away by contractions of the bell or umbrella and develops four **gonads** or reproductive organs which may be male or female, but only one kind on each bell. The sperms are set free in the water, swim about by means of their vibratile tails, and so reach the egg cells, which become fertilised. Thereupon the egg cell develops into a ciliated **larva** which swims about and ultimately fixes itself down on a seaweed or on a piece of timber in the water and so begins a new hydroid colony. Here, just as in ferns, there is a marked alternation of generations, the asexual being the sedentary form, the sexual being the swimming and temporary form.

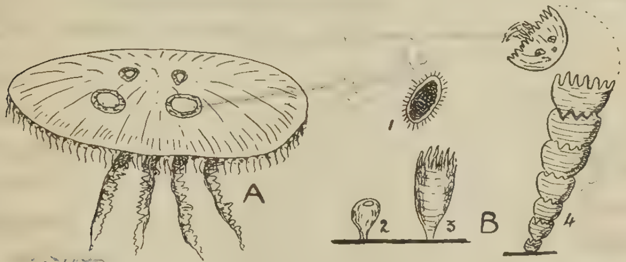

Fig. 4.—Jellyfish. A, adult Aurelia ; B, stages in development from ciliated larva

✓The **Jellyfish** (Fig. 4) differs from the foregoing type mainly in the fact that the swimming-bell stage is the dominant generation, the asexual generation or fixed stage being only a temporary phase.

The Common Jellyfish, *Aurelia*, found near our shores has an umbrella the edges of which are fringed with tentacles.

In the centre of the under side is a "mouth" with, at each corner, a frilled lobe hanging downwards. Showing through the umbrella, but on the under side, are four horseshoe-shaped **gonads** containing the sexual cells, male on one individual, female on another. Ova and spermatozoa are liberated and fertilisation takes place in the water. The animal is well supplied with stinging cells and shows a well-developed nervous system.

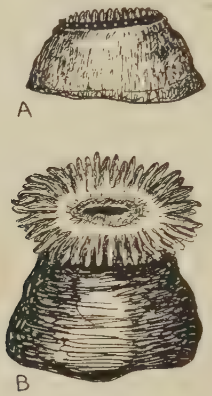

Fig. 5.—Sea-Anemone. A, almost closed; B, fully expanded

Life history. — The fertilised ovum produces a larva which is free-swimming but soon settles down on a rock or piece of seaweed. It proceeds to grow into a vase-shaped structure which gradually becomes horizontally divided into a series of plates or saucers with the concave side upwards. Each around its margin produces tentacles, and one by one a "saucer" is set free, turns over and goes on its way a young Jellyfish.

The **Sea-Anemone** (Fig. 5) is closely allied to the Coelenterates already described. In a very general way it may be compared to a Jellyfish upside down and fixed in one position. There is a central "mouth" surrounded by a series of comparatively large tentacles by the movements of which food material is driven inwards. When the tide recedes, or when the animal is attacked, the tentacles are withdrawn within the mouth and all that is seen is a spherical mass of jelly-like, but tough, material. The animal, when irritated, sends out long white threads which are well supplied with stinging cells by means of which the animals on which it lives are brought into subjection. [illegible]

Within the body wall is the general cavity, which is not, as in Hydra and Aurelia, an undivided chamber, but has a series of partitions or septa which (always six or a multiple of six in number) run in from the outer wall towards the centre, meeting the gullet tube, which is formed by a tucking in of the mouth. Below this the septa do not meet but remain open. On them are strong muscles, used in the retraction of the tentacles, and also the gonads, which are unisexual, *i.e.* containing either eggs or sperms, but not both. The fertilised eggs seem to undergo considerable development withint he parent Anemone and escape as ciliated larvæ, which ultimately settle down to a sedentary existence.

Corals.—In the colonial Coelenterates, *e.g.* *Obelia*, the individuals living in the cups are often termed **polyps.** When such polyps secrete stony cups in which to live, a mass of calcareous material is gradually built up. As the coral polyps bud, the stony skeleton is gradually being added to, and thus coral reefs come into being. The *Red Coral*, used for ornaments, is a special type, about a foot high, found in the Mediterranean. The red solid is the central axis of the colony. Mat

CHAPTER III

ECHINODERMATA: STARFISHES AND SEA-URCHINS

4th Phyl

Echinodermata (Gk. *echinos*, a hedgehog, *derma*, the skin).—The name suggests that the animals of this group have a spiny or prickly skin, and this is more or less true. They are distinguished from the Coelenterates by the presence of a body cavity (*coelom*) through which the intestine (*enteron*) passes. They are radially symmetrical, commonly with five rays, the enclosing skin being hardened with calcareous plates and spines. They include the **Starfishes**, the **Sea-Urchins** and the **Crinoids**. The last were important in former times, and their remains formed the Crinoidal Limestone which is so abundant. They are now represented by a few forms only, the *Feather Stars* or Sea-Lilies.

✓ **Starfishes.**—The Starfish, *Asterias* (Fig. 6), is a common seashore object easily recognised. It has five "arms" or rays on which are calcareous plates bearing small spines. The central portion to which the arms are attached is comparatively small and is known as the **disc**. Each of the arms has, on the under side, a deep groove in which are numerous thread-like structures expanding at their ends to form suckers. These structures are known as **tube-feet**. In the centre of the under side (ventral surface) of the disc is the **mouth**, while in the centre of the upper side (dorsal surface) is a small aperture or **anus**. Near this, and placed in the angle formed by two arms, is a round perforated plate, the **madreporite**.

Internal structure.—The mouth leads into a stomach which is followed by a short intestine or gut which ends in the arms. Just above the stomach are five large glandular structures, one to each arm, the **hepatic** (or **liver**) **glands**, which are said to produce digestive juices.

In the angles formed by the arms are five pairs of sexual organs or **gonads** which produce either sperms or ova, the sexes being similar but separate. Both sperms and ova are liberated into the water, where fertilisation takes place, a free-swimming **larva** being produced.

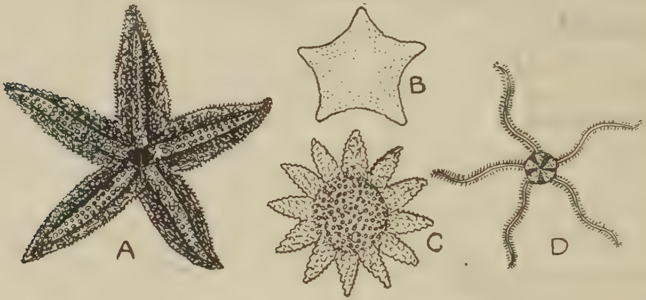

FIG. 6.—Starfishes. A, Common Starfish; B, Pincushion Star; C, Sun Star; D, Brittle Star

The **tube-feet**, by means of which the animal moves slowly along, are operated by what is known as a **water-vascular system**. Water is taken in at the madreporite and passes down to a tubular ring which encloses the gullet just above the mouth. From this ring a branch passes to each of the arms and with this the tube-feet are connected. By the use of special muscles in the vicinity of each tube-foot pressure is set up in the water within and the tube-feet are protruded, the suckers at their ends taking a firm hold of stationary objects. By contraction of the feet the body is pulled forward, whereupon the process is repeated. As the feet operate in rotation a more or less continuous movement of the whole animal is produced. This action may be well seen in a glass vessel of sea-water, and if the animal be placed on its back it loses no time in righting itself by means of these insignificant but useful organs.

Habits.—The Starfish feeds mainly on shell-fish, *e.g.* oysters, mussels and other bivalves. It is able by means of its tube-feet to pull the two halves of the shell asunder, whereupon it protrudes its stomach through its own mouth and envelops the succulent morsel.

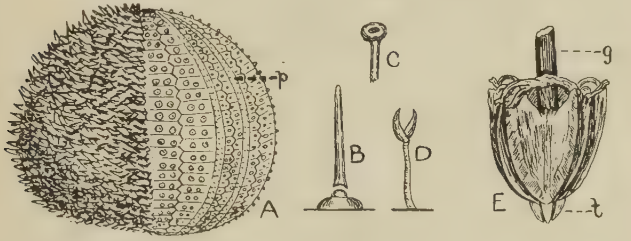

Fig. 7.—Sea-Urchin. A, test with spines partially removed—p=pores through which tube-feet protrude ; B, a spine ; C, a tube-foot ; D, one of the pedicellariae ; E, Aristotle's Lantern—g=gullet ; t=teeth

An interesting fact is the ease with which a lost arm can be regenerated, and cases are known where the severed arm has reproduced a whole Starfish.

Amongst the spines are special ones which can snap together like scissors or pincers. These have been called **pedicellariae** (Fig. 7), and are believed to have the special function of keeping the outer surface of the animal clean.

The only sense organs present are the little reddish **eye spots**, found one at the tip of each arm. Each is connected by a radial nerve with a central nerve ring which, along with the water canal, encircles the gullet above the mouth.

Other types of Starfish (Fig. 6).—The **Sun Star** (*Solaster*) has a relatively larger disc and twelve or more short arms. The **Brittle Stars** have very thin flexible arms which contain no part of the vital organs. The arms are very brittle, being very readily shed and regenerated.

Sea-Urchins (Fig. 7).—The systematic name of the common Sea-Urchin is *Echinus* (L. *Echinus*, a hedgehog). It is interesting to note that in some parts of Scotland the Hedgehog is known as the "Hurchin." Hence both scientific and common names suggest the similarity to that prickly land animal.

The Sea-Urchin has a continuous hard shell or *test*, made up of five distinct radial parts, such as might be obtained if the five arms of a Starfish were bent upwards until they met dorsally. There are five double rows of tube-feet, which are protruded through small holes in the shell and which are operated by a water-vascular system similar to that of the Starfish. There are many spines (in some species they are quite stilt-like), which are joined to small knobs on the shell by ball-and-socket joints. **Pedicellariae** (Fig. 7) are also present in considerable numbers. The mouth, as before, is below and displays five chisel-shaped teeth which are supported by a bony cage, known as *Aristotle's Lantern* (Fig. 7). The intestine is fairly long, forming two and a half coils around the inside of the shell before it reaches the anus, which is dorsal. A **madreporite** is present as in the Starfish. The animal is mainly vegetarian, living upon seaweeds, which it cuts with its sharp teeth.

The **gonads** at times almost fill the interior of the shell. They are edible; hence the name of the Common Sea-Urchin, *Echinus esculentus.* The sexes are separate, sperms and ova being shed into the water.

Other types of Sea-Urchin.—In addition to the Common Sea-Urchin, other forms are found, *e.g. Echinus miliaris*, which is very much smaller and bears purple-tipped spines on a flatter test, and various **Heart-Urchins**, which have lost the radial symmetry and are heart-shaped. The anus in the latter is not dorsal but posterior ; the mouth has no teeth, since the animal burrows in the sand and feeds on organic particles which it finds therein. The tube-feet are in leaf-shaped areas and not in radial rows, the spines are often unequally sized, and the test is very fragile.

CHAPTER IV

WORMS 5th Phylum.

Worms.—The name "Worm" is applied to numerous animals which differ widely amongst themselves. For our purpose they may be divided into two main groups: (a) *Unsegmented Worms* and (b) *Segmented Worms.* All these show a departure from the radial symmetry which the previous groups exhibited, and are provided with a "head" and "tail." As one part of the body constantly moves in front, it is natural to expect that a concentration of sensory cells, the rudimentary brain, should appear in that region.

Unsegmented Worms.—These are degenerate types and mainly parasitic. They live in the interiors of other animals and hence find their food ready-made. They show little or no body cavity. There are two main groups: *Flat Worms* and *Round Worms.*

Flat Worms.—1. The **Liver Fluke** of the sheep, *Distomum hepaticum* (Fig. 8), which causes a disease called "Liver Rot."

The animal is flat, oval and about an inch long. It is provided with two suckers (hence the name *Distomum*), by means of which it clings to its host, one being at the head end and enclosing the mouth, the other farther back

Life history.—The eggs of the Fluke escape from the liver by way of the bile duct, pass along the intestines of the sheep and ultimately reach the ground. The larva escapes from the egg case and can live only in water. Even then its only chance of continued existence is the presence of a water-snail (*Limnaea*). It lives for some time in the pulmonary chamber (see Snail, p. 49) of this animal in an encysted state. The cyst divides up into a number of larvae of a different type. These escape from the snail and moor themselves to the stems of plants growing at the edge of the water. But they soon die unless they happen to be swallowed by a sheep, when they make for the liver and grow into Liver Flukes, thus completing the cycle of a career full of risks. When risks are great the

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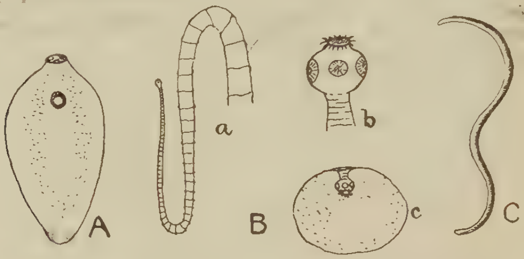

FIG. 8.—Unsegmented Worms. A, Liver Fluke; B, Tape-Worm—a=adult worm; b=head enlarged, showing hooks and suckers; c=bladder-worm stage (with head inside); C, Round Worm of the Horse

"prodigality of nature" steps in: a single Liver Fluke may produce half-a-million eggs.

2. The **Tape-Worm** (Fig. 8), which infests the intestines of many animals, is in many ways similar, but it grows in length (in sections) and may eventually kill the host. It has a small globular head which is provided with both suckers and hooks which make this parasite almost impossible to dislodge. Like the Liver Fluke it demands a second host to carry out its life cycle. A Tape-Worm of man passes its second stage in the muscles of the pig in the form of a bladder-like cyst. This may be swallowed by man in infested pork.

One Tape-Worm of the dog passes its "bladder-worm" stage in the brain of the sheep, in which animal it causes a disease known as "Sturdie" or "Staggers."

Round Worms.—These too are parasitic. Common examples are *Ascaris*, the "Round Worm" of the horse and of man (Fig. 8), and *Trichina*, which spends part of its time in man, and part in the muscles of the pig, where it encysts in a small spiral coil. Flesh so infected is known as "measly pork."

Segmented Worms.—These are made up of a continuous series of rings or segments which are not merely external but show in an internal dissection. They may be divided into three groups:

1. Worms with no external appendages and few bristles; land or fresh-water forms, *e.g.* the Earth-Worm.

2. Worms with paddles or *parapodia* and many bristles; marine forms, *e.g.* Lob-Worm.

3. Leeches, which have neither parapodia nor bristles; found in fresh water, *e.g.* Horse Leech.

The Earth-Worm (Fig. 9).—**External appearance.**—The body is long, narrow, cylindrical, tapering at both ends. Skin is slimy, iridescent, and reddish in appearance, owing to the blood-vessels showing through the skin. The body is made up of many segments. On the under side of the first is the mouth, which has an overhanging lip, while in the last segment is the vent or **anus**.

In mature Earth-Worms there is a swollen part, the **clitellum** or **saddle**, due to the presence of glands which secrete the egg capsule. On the under side of the worm there are four double rows of **bristles** or **setae**, used in movement, *i.e.* there are four pairs to each segment.

Respiration.—Aeration of the blood goes on through the skin. The blood is red, owing to the presence of haemoglobin (Gk. *haima*, blood) which is in the fluid part of the blood and not in the corpuscles as in the blood of higher animals. Circulation of the blood is brought about by the action of five pairs of contractile "hearts" situated in segments seven to eleven. Each pair encircles the alimentary canal, one on each side, thus forming a ring. The main blood-vessel is along the back of the animal.

Nervous system.—In the third segment there are two masses of nerve cells (*ganglia*) situated above the gullet. These are linked together, and from each a nerve cord runs down each side of the digestive tract, uniting below with a ventral nerve cord which runs along the under side of the animal. This gives off nerves in each segment.

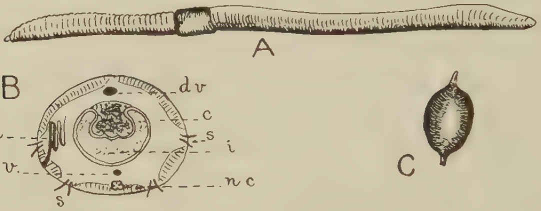

FIG. 9.—Earth-Worm. A, adult worm, showing clitellum ; B, a transverse section—c, body cavity ; i = intestine ; n = nephridium ; s = setae ; d.v. = dorsal blood-vessel ; v.v. = ventral blood-vessel ; n.c. = nerve cord ; C, egg capsule

The chain of ganglia from which the latter arise is easily seen. It should be noted that in Vertebrates the nerve cord is dorsal (*spinal cord*), while the main blood-vessels are ventral. There are no special sense organs.

Digestive tract.—The simple mouth leads, through the **gullet** or **oesophagus**, to a **crop** or storage pocket, from which the swallowed material passes to a **gizzard**, which is a strong muscular organ in which the food is ground up. A long straight intestine, where absorption takes place, leads to the vent or anus.

Excretion.—In each segment there is a pair of **nephridia** (Gk. *nephros*, a kidney), which are little coiled tubes, each opening to the exterior through a small pore in the segment immediately in front of that in which it lies. These nephridia rid the body of the finer waste products. In the higher animals similar tubular structures are massed together to form the kidney.

Reproduction.—The Earth-Worm produces both eggs and sperms, *i.e.* is *hermaphrodite* (*cf.* many flowering plants). The sperms reach the exterior through two small openings, with swollen lips, on the under surface of segment fifteen, while the ovaries open to the exterior through two similar but much smaller openings in segment fourteen.

Sperms from one individual are passed into special storage pockets in another. Eggs and some of these sperms are passed out and enclosed in a ring of substance secreted by the glands of the clitellum. Out of this ring the worm slips backwards, the ends of the little tube contract and a capsule or cocoon (Fig. 9), about the size of a grain of wheat, is produced. As a rule only one egg develops to maturity, the chosen embryo eating up its neighbours, being for the only time in its life carnivorous. The little worm is perfect when it makes its way out of the cocoon.

Regeneration.—If a worm be cut in two a new hinder end can be developed in place of the lost segments, and, in favourable circumstances, a new head end may be regenerated, *cf.* the power of regeneration in the Starfish.

Mode of life.—The Earth-Worm burrows by swallowing the soil, extracting what nutriment the soil may contain and voiding the major part through the anus in the form of "worm-casts."

During the day it remains below ground, coming forth mainly at night. The rear end of the worm can be flattened out, and this often remains in the burrow so that the worm can rapidly retreat if danger threatens. The strong grip which this flattening gives, assisted by the action of the setae, is well illustrated in the tug-of-war between the worm and, say, a mavis. The food is vegetarian mainly. In addition to that extracted from the soil the worm also devours leaves and other vegetable material. These are dragged down the burrows, and leaf-stalks can be seen in any garden half pulled into the burrows of worms. When worms are feeding mainly on soil-contents the worm-casts are many, but when feeding chiefly on leaves these are not nearly so frequent.

Action of Earth-Worms on the soil.—They swallow and pulverise the soil and bring it to the surface, and the burrows themselves help to make the soil penetrable to air and water. This tends to produce a soil suitable for the growth of plants and for the activity of bacteria which have much to do with the preparation of the soil food of plants.

Charles Darwin studied very closely the work of Earth-Worms. His experiments may be easily repeated on a chosen piece of lawn by sweeping it clean and subsequently collecting, counting, drying and weighing the worm-casts. He found that in ordinary soil there are about 50,000 worms per acre, and that ten tons of soil pass through the bodies of these worms in a year, or, to put it in another way, in ten years a finely divided surface soil, two inches deep, is produced. In his *Vegetable Mould and Earthworms* he says:

"When we behold a wide turf-covered expanse . . . it is a marvellous reflection that the whole of the superficial mould over any such expanse has passed, and will again pass, every few years, through the bodies of worms. The plough is one of the most ancient and most valuable of man's inventions; but long before he existed the land was in fact regularly ploughed and still continues to be ploughed by Earthworms. It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organised creatures."

Paddle Worms.—These agree with the Earth-Worm in having a body made up of segments bearing bristles. They differ in having a more distinct head, often with eyes and feelers upon it, breathing organs or **gills** (they are all marine), and **parapodia** (Gk. *podos*, the foot) or "paddles" on which are borne the more numerous bristles, often in tufts. Common examples are the **Lob-Worm**, **Nereis**, the **Sea-Mouse**, and many sedentary forms which live in tubes.

The **Lob-Worm** or **Lug-Worm**, *Arenicola* (Fig. 10), is much used by fishermen as bait. It burrows in the sand and is eight inches or more in length. Castings or "sand-ropes" indicate at low tide the presence of these animals. Their movements in the burrows are swift and they are not always easy to get with the spade.

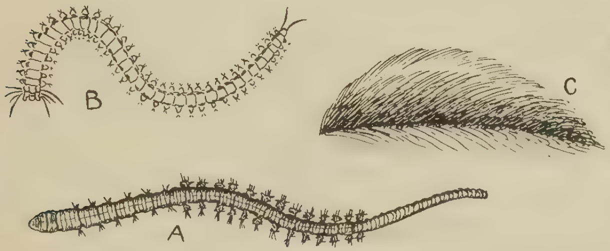

FIG. 10.—Segmented Worms. A, *Arenicola*, the Lob-Worm; B, *Nereis*, a Paddle-Worm; C, *Aphrodite*, the Sea-Mouse

General characters.—There are three distinct regions in the body: (*a*) the first seven segments have bristles only (the first segment has none); (*b*) the next thirteen segments have bristles and external feathery gills by means of which the animal extracts oxygen dissolved in the water; and (*c*) the remaining segments, variable in number, have neither bristles nor gills.

Nereis (Fig. 10) is found in the sand but can also swim actively. It has no external gills. The head regions are much more highly developed. A lobe overhanging the mouth, the **prostomium**, bears eyes and tentacles, as well as larger palps or feeling organs. On the **peristomium**, the first true segment and bearing the mouth, are four paired **cirri**, the name given to long slender hair-like tentacles. Two cirri are also present at the hinder end. Each segment is extended laterally into parapodia, which bear tufts of bristles.

The **Sea-Mouse**, *Aphrodite* (Fig. 10).—This at first sight shows little of the worm character, being about the size and shape of a mouse. It burrows in the mud of the estuaries round our coasts. It is covered with long hairs, which, when cleaned, are beautifully iridescent. The under side of the animal shows that it is made up in segments, and its internal structure justifies its position amongst segmented worms.

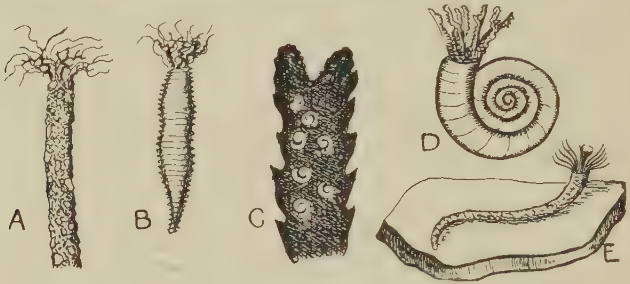

FIG. 11.—Tube-dwelling Worms. A, *Terebella*, the Sand-Mason; B, *Terebella*, the tube removed; C, *Spirorbis* on seaweed; D, *Spirorbis*, enlarged; E, *Serpula*

Sedentary Worms (Fig. 11).—1. The **Sand-Mason** (*Terebella*).—This worm builds a flexible tube of grains of sand and fragments of shell, all neatly cemented together. It protrudes from one end a fringe of delicate tentacles amongst which are three pairs of bright red branched gills. The animal can be completely retracted into the tube, where it is safe from the attacks of enemies. *Pectinaria* is another worm which lives in a similar tube, which however is composed entirely of sand and has a much more regular appearance.

2. **Other Tubicolous Worms.**—*Serpula* lives in a limy tube attached to rocks, the tube being one to two inches long. *Spirorbis* produces a tiny coiled tube of similar material, found attached to seaweeds. *Pomatoceros* is somewhat similar to Serpula but smaller and has longitudinal ridges on the tube.

Leeches.—Leeches are found in water or damp earth. They move through the water by an undulating motion of the whole body, or may progress on the pond bottom by a "looping" action by means of the suckers which are present one at each end of the body. The **Horse Leech** may be three inches long and has a stoutly built segmented body. The sucker at the posterior end is for adhesion only, the other one surrounds the mouth. The mouth has three saw-like jaws by means of which it pierces the skin of its victim, from which it draws blood. The crop consists of a series of pouches in which the blood is stored, clotting being prevented by the action of a special ferment produced. The **Medicinal Leech** is imported from the Continent. It was formerly used largely for blood-letting, a practice which has fallen into disuse. An interesting relic of this custom is the brass saucer on the barber's pole, the barbers of former times being the recognised blood-letters.

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CHAPTER V

MOLLUSCA 6th Phylum.

Mollusca, commonly termed "Shell-Fish," are soft-bodied animals, covered, usually, by a calcareous shell which is secreted by a special fold of the body wall, the **mantle**. The latter may cover the body in one piece or may hang down on the two sides of the body as separate flaps or mantle lobes, the shell in this case being in two parts or valves. Most molluscs fall into one of two classes:

1. *Univalves*: Snail, Slug, Whelk, Limpet, Periwinkle.
2. *Bivalves*: Mussels, Oysters, Cockles.

The organ of locomotion is a single, ventrally placed, muscular mass known as the *foot*. There is an alimentary canal distinct from the body cavity or coelom, but the latter is much reduced, being the pericardium or chamber in which the heart lies.

The Garden Snail, *Helix* (Fig. 12).—This may be taken as a type, though the twisted nature of the body makes dissection difficult. For this purpose a good-sized slug is preferable.

Shell.—The shell is brownish or yellowish, in the form of a spiral with four and a half turns, and is placed obliquely on the body with the apex on the right side.

General characters.—During movement the foot and head are protruded from the shell. The **head** has two pairs of tentacles, the longer pair above. The latter have eyes at their tips and are hollow like the finger of a glove The tip containing the eye can be withdrawn within the tentacle by special muscles. There is no neck.

The **mouth** has two lips inside of which is a rasping tongue, the **radula**, by which vegetable matter is scraped away and eaten. The rasp has 145 transverse rows from back to front, with 107 teeth in each row, making up a formidable weapon, as those who keep gardens have reason to know.

The **foot** is a large, very muscular structure, by means of which the animal moves. It creeps forward at a definite rate; it cannot hurry or move backwards. Its progress over rough ground is assisted by a slime produced by a gland and poured out at the front end of the foot. The strength of this organ has been demonstrated by simple experiments which show that a snail can drag up a vertical surface a load nine times its own weight, or along a horizontal surface a load fifty times its own weight.

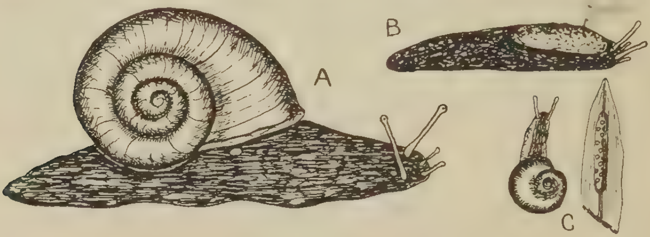

Fig. 12.—Snails and Slugs. A, the Garden Snail; B, the Black Slug; C, the Pond Snail, showing eggs on water-weed

Respiration.—At the edge of the shell there is a thick soft frill, the **collar**. At a point on the right of this collar is an opening through which air is admitted into a respiratory or **pulmonary chamber**, which lies between the mantle and the body. Aeration of the blood takes place through the thin wall which separates this chamber from the body.

Internal organs.—The body of the snail is twisted into the spiral shell and forms a mass known as the **visceral hump**. This contains the intestines, heart and liver. The vent or anus adjoins the respiratory opening.

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Reproduction. — The Snail, like the Earth-Worm, is hermaphrodite, producing both eggs and sperms. Here also cross-fertilisation is the rule. The eggs are fertilised within the body before being enclosed in calcareous shells, and may be from forty to one hundred in number. They pass out of a special **genital pore**, on the right side of the head, and are deposited in a hole in the earth, being then covered up with soil. Development seems to be direct and a miniature adult is hatched in about three weeks.

Hibernation.—During winter Snails suspend activity and may be found, often in groups, attached to the under sides of logs, stones or even large leaves, and sometimes on sheltered walls. The opening of the shell is sealed up by a thin partition, except for a small hole left for the access of air.

Slugs (Fig. 12).—Slugs are very similar in structure to Snails. The body is not coiled and there is no visible shell. There is, however, a shield-shaped portion which may contain within it some calcareous matter. This suggests that Slugs once had shells but have dispensed with them. It is stated that in the early stages of development the young Slug has a tiny spiral shell. The respiratory chamber is small, but the pulsating of the respiratory opening can be observed. The Slugs commonly found are the **Black Slug** (*Arion*), which may be two to four inches long, and the **Grey Field Slug** (*Limax*), which is usually less than an inch long.

Other Univalves (Fig. 13).—The **Pond Snail**, *Limnaea* (Fig. 12), has already been mentioned (see p. 37) and is one of various Fresh-Water Snails. The seashore provides the **Periwinkle** (*Littorina*), the **Whelk** or "Buckie" (*Buccinum*), and the **Limpet** (*Patella*), which clings so firmly to the rocks. The Whelk, the **Dog-Whelk** (*Nassa*) and the smaller **Dog-Whelk** (*Purpura*) have a respiratory siphon or tube which passes through a notch in the shell.

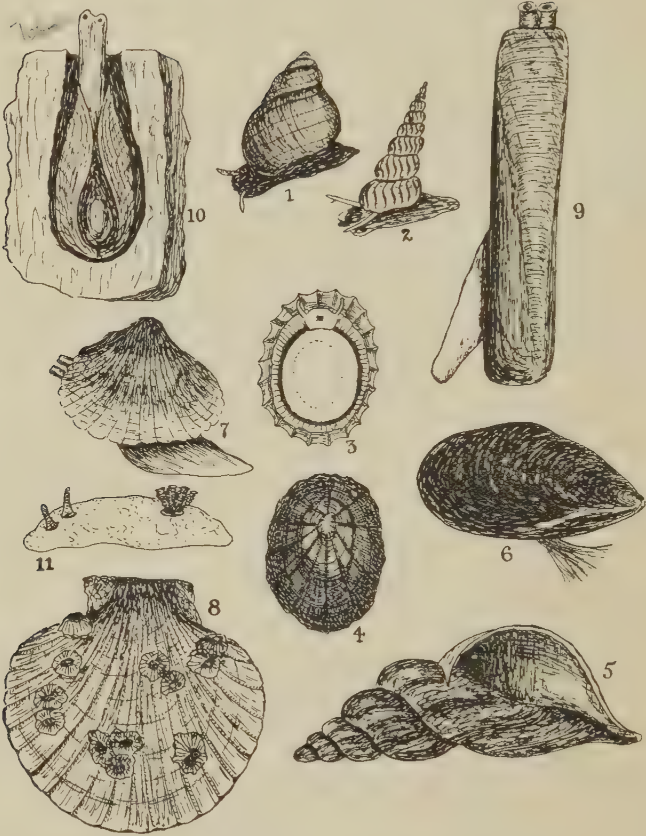

Fig. 13.—Molluscs. 1. Periwinkle; 2. Wentle-trap; 3. Limpet (under side); 4. Limpet (from above); 5. Whelk; 6. Mussel (note the Byssus threads by which it is attached to rocks); 7. Cockle (note the foot and respiratory siphons); 8. Scallop (with barnacles); 9. Razor Shell; 10. Pholas, burrowing in limestone; 11. Doris, a Nudibranch or shell-less mollusc (note the plume-like gills)

The Whelks are carnivorous. The others mentioned are mostly vegetarian. *Purpura* was the source of Tyrian purple dye. The egg cases of the Buckie, in groups about the size of one's fist, are commonly found thrown up on the shore, while the egg capsules of the Dog-Whelk may be found as little yellow cups under ledges of rock. The eggs of the Pond-Snail are enclosed in a jelly-like mass and attached to water-weeds (Fig. 12).

Bivalves (Fig. 13).—Bivalves lead sedentary lives, protected from attacks of enemies by the two valves of the shell, which can be rapidly closed by powerful muscles. Almost the only risk they run is from other molluscs, the Whelks, which are able to pierce their shells and suck out the contents. They obtain their food from the current of water which they suck in through the inhalant siphon (*cf.* Whelks). After passing over the gills, which extract the oxygen required, and having food material extracted by the simple mouth, the water passes out again by another siphon tube (exhalant). The anus opens near the exhalant siphon and waste products are thus speedily carried away. The chief examples of this group are:

The **Fresh-Water Mussel** (*Anodon*), found in ponds, usually four to six inches long.

The **Sea-Mussel** (*Mytilus*), found in large numbers on in-shore rocks and on the piles of piers. Is edible.

The **Cockle** (*Cardium*), lives buried in sand, but has a very large powerful foot by which it can leap on the sand. When buried it leaves the tips of its respiratory siphons just above the surface of the sand. Is edible.

The **Oyster** (*Ostrea*), cultivated as a delicacy. Along with other bivalves it is noted for the production of pearls and also for the mother-of-pearl which lines the inside of the shell. Pearls are built up by a secretion which is stimulated by the presence of an irritating grain of sand or a minute parasite. The foreign body is enclosed by numerous layers of this secretion. Fresh-Water Mussels produce quite good pearls, which are hunted for in many places in Scotland where this mussel is plentiful.

The **Scallop** (*Pecten*), has a fan-shaped, beautifully coloured shell, common on the seashore. The edge of the mantle possesses rudimentary eyes. The animal can swim by moving the shell valves.

The **Razor Shell** (*Solen*), burrows in the sand, even deeper than the Cockle. The shells, at least, are often found washed up on the shore. It is said to swim by squirting out water from the mantle cavity.

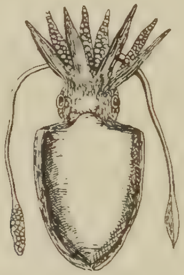

FIG. 14.—Squid or Cuttle-Fish (*Sepia*)

Boring Molluscs (Fig. 13).—Some bivalves are able to bore cylindrical holes in rocks and timber, where they live in perfect safety. The shells being more or less unnecessary tend to be degenerate, but are always present. Common examples are *Pholas*, which burrows into limestone rock, and *Teredo*, the Ship-Worm, which bores into timber and is a menace to the wooden ship.

Shell-less Molluscs (Fig. 13).—In addition to the Slugs already mentioned there are several marine forms, called **Sea-Slugs** or **Nudibranchs**, which have no shell or only a trace. They have plume-like external gills arising from the dorsal surface, giving the animal, when in the water, a very graceful appearance. Examples are *Doris*

Eolis, *Dendronotus*, *Doto*, all of which are quite common, *e.g.* in the Firth of Forth.

A third type of Mollusc.—Related to the above types, but differing vastly in general appearance, are the **Squid** or **Cuttle-Fish** (Fig. 14) and the **Octopus**. The Cuttle-Fish (*Sepia*) is very common round our shores. It has eight short and two long "arms" or tentacles provided with strong suckers. It swims (usually backwards) by expelling water forcibly, and when pursued ejects a quantity of black ink which provides the sort of "smoke screen" which we heard about during the Great War. This black substance is used in the manufacture of "sepia" colour. Within the animal, and apparently acting as a support, is a shell-like bone (or bone-like shell), *cuttle-bone*, which is used industrially for polishing and other purposes. The animal has well-developed eyes, and the mouth is provided with a powerful beak quite like that of the parrot. The eggs of the Cuttle-Fish are commonly found cast up on the seashore, and are often called "sea-grapes" from their resemblance to a bunch of black grapes.

The **Octopus** has only eight arms, is much larger than, and not nearly so active as, *Sepia*. It lurks amongst and creeps about the rocks, generally in deep water.

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CHAPTER VI

ARTHROPODA 4th Phylum.

THE **Arthropods** (Gk. *arthron*, a joint, *podos*, the foot), the animals with jointed feet, or better, with jointed legs, form an immense group which includes at least half of all the species of animals known. When it is recognised that there are some 200,000 kinds of insect known, and that the group includes these, its extent can be better imagined than described. In spite of such enormous numbers the Arthropoda fall into four well-marked classes, whose general characters are fairly distinct. These classes are placed together into one group or *phylum* because they have certain characteristics in common which mark them off from all other animals.

General characters of Arthropods. — They, like the Worms, are segmented animals. The brain is dorsal and is connected by a ring round the gullet with a ventral nerve cord. The heart and the main blood-vessels are dorsal. Unlike the Worms, however, they possess, in some or all of the segments, jointed appendages for locomotion, the whole of the body and all the appendages being encased in a horny coat of mail secreted by the skin and composed of *chitin* hardened with lime salts, *cf.* the thickened cuticle in the leaves and stems of plants with which this dead product of the epidermis, really the cuticle, is analogous. Between the joints of the armour-plate the cuticle contains no lime and is therefore pliable.

The shell of a Mollusc continues to grow as required, by the addition of rings of material at its edges, and serves the animal for its lifetime. In the Arthropoda this does not occur, and when the animal becomes "too big for its boots" the latter must be discarded and new ones produced. This moulting process takes place many times during the life of the animal and, during these periods when the outer defences are thus removed, a secluded existence is recommended. The sexes are separate, cross-fertilisation takes place, and the egg gives rise, not to a young adult as in the Worm, but to a larva or young form which is quite different from the adult, into which it grows by a series of changes or *metamorphoses.* The relationships of the Arthropoda were for a long time obscure, until the "missing link" was discovered in *Peripatus*, a worm-like creature with legs. This seems to show the possibility of the Arthropod ancestors having belonged to the Worms.

Group divisions.—The Arthropoda may be divided into four classes:

1. *Crustacea*, *e.g.* Lobsters, Crabs, Wood-Lice ("Slaters") Sandhoppers, Barnacles, etc. Nearly all live in water, breathe by gills, have two pairs of feelers or antennae, and have the body divided into three parts—viz. head, thorax, abdomen.

2. *Arachnida*, *e.g.* Spiders, Mites, Scorpions, etc. These are air-breathers, have no antennae, and have the head and thorax fused, so that they appear to have only two regions in the body. Typically, they have eight legs (four pairs).

3. *Myriopoda*, *e.g.* Millipedes and Centipedes. These are air-breathers, have one pair of antennae, the body being made up of numerous segments and not differentiated into thorax and abdomen. Each segment has one or two pairs of jointed legs.

4. *Insecta*, *e.g.* Butterflies and Moths, Beetles, Dragonflies, Cockroaches, Ants, Bees, Wasps, House Flies, Gnats, etc. These are air-breathers, have one pair of antennae, definite head, thorax and abdomen. They have six legs (three pairs). No marw

- organs of
moves about by walk.

CRUSTACEA

Crustacea are aquatic Arthropods, breathing by special gill structures, these being thin-walled feathery processes on each side of the body (*cf.* Fish, p. 81), usually hidden under the **carapace** or **shield** which covers the head and thorax. Water passes over these gills by rhythmic movements of little plates belonging to the mouth appendages, oxygen being extracted by the blood which circulates in the gills.

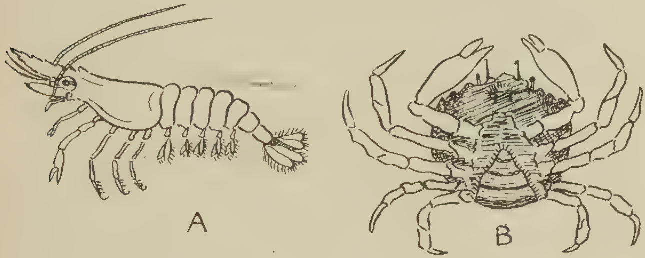

FIG. 15.—Crustaceans. A, Prawn; B, Shore-Crab (note the tucked-in tail)

The head region bears two pairs of antennae, a pair of stalked eyes, and a mouth enclosed by a pair of **mandibles** or biting jaws, and two pairs of softer appendages, the **maxillae**. The thorax bears a pair of large claws, usually of unequal size, and some legs used for walking. The abdominal region has a number of appendages, one pair to each segment, which are modified for swimming. These are the **swimmerets**, each consisting of two flat branches fringed with hairs, the last pair being broad and flat, forming the tail.

Hence the animal can (1) walk on the bottom; (2) swim forwards gently by means of the swimmerets; and (3) retreat rapidly by a downward stroke of the tail.

Kinds of Crustaceans.—1. **Decapods** (Gk. *deca*, ten, *podos*, the foot).—These have five pairs of legs, and may be:

(a) *Long-tailed*, *e.g.* Prawn (Fig. 15), Shrimp, Lobster, Crayfish. In the Prawn and Shrimp the swimmerets are well developed, whereas in the Lobster they are of much less use, the latter being mainly a creeping animal.

(b) *Short-tailed*, the abdominal segments being tucked away under the body, *e.g.* Crabs (Fig. 15). Some Crabs show interesting cases of symbiosis or partnership. They mask their shells with other animals which screen them from view, *e.g.* Sponges, Sea-Anemones, Zoophytes. The attached "camouflage" benefits by being carried about from place to place, and, possibly, from the crumbs which are derived from the Crab's table.

(c) *Soft-tailed*, *e.g.* Hermit Crabs. The Hermit Crab does not produce a shell on the hinder part of the body, but pushes the defenceless part into a vacated shell, commonly that of a Whelk, moving to more commodious quarters when compelled by increase in size.

2. **Amphipods** (Gk. *amphi*, both or two).—These have two kinds of legs, the forward ones pointing to the head, the others being directed backwards. These animals are laterally compressed, and commonly lie and move on their flattened sides, *e.g.* *Gammarus* (Fig. 16), which may be found under almost any stone on the seashore, another species being found in fresh water ("Fresh-Water Shrimp"). The males are much larger than the females and may be seen carrying the latter held in the anterior legs. The **Sandhoppers** or **Beach Fleas** are very similar and, like Gammarus, are useful scavengers of the seashore.

3. **Isopods** (Gk. *isos*, equal).—These have legs all of one

kind. They are flattened from above downwards (*i.e.* parallel to the ground), and may be termed, generally, *Slaters*. One, *Asellus*, the **Water-Slater** or **Water-Louse** (Fig. 16), is found, like Gammarus, under stones on the seashore, while another, the **Wood-Louse** (the real Louse is an insect) or **Land-Slater**, is common under stones or pieces of wood in damp places away from the shore. They breathe by gills and are thus dependent upon moisture.

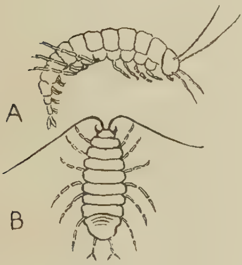

Fig. 16.—Crustaceans
A, Gammarus ; B, Water-Slater

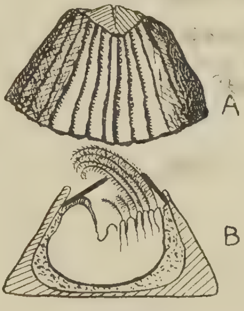

Fig. 17.—Acorn-Shell or Barnacle
A, closed ; B, sectional diagram

4. **Lower forms.**—These are mainly small almost transparent forms, many of them microscopic, which dart about in the sea and also in fresh water. They constitute the food of many fishes and other forms of aquatic life. A common example is the **Water-Flea** (*Daphnia*) found in fresh water, while in the sea the variety is prodigious.

A highly specialised and degenerate form of Crustacean is the **Barnacle** or **Acorn-Shell**, *Balanus* (Fig. 17), which, in countless numbers, covers the rocks between tide-marks. If observed under water, the shells may be seen to gape apart, when waving plumes appear. These are really the legs of the animal within. It has arrived at the *non plus ultra* of indolence, because it lies on its back and kicks its food into its mouth with its feet. The young stage is free-swimming, but it soon fastens its head to a convenient rock surface and remains there for the rest of its career.

Akin to this is the **Ship Barnacle** (*Lepas*), which is found attached to the bottoms of ships or floating timber by long fleshy stalks formed of the modified head regions. It used to be called the Goose Barnacle, it having been believed, on the evidence of romantic observers, that from these sedentary animals there hatched out a tiny bird which became a goose.

INSECTA

Insects amongst invertebrate animals (*i.e.* those with no backbone) have, like birds amongst the Vertebrates, taken to the air and acquired the power of flight, a faculty which gives them many advantages in the struggle for existence. Like birds, they have a very complete and efficient respiratory system, the very thorough oxygenation of the blood being correlated to their active mode of existence. In development they undergo a marked metamorphosis, the larval stages being terrestrial or, as is often the case, aquatic. Larvae and adults agree in being segmented. The body of the adult shows three regions, as in the typical Crustacean — viz. head, thorax, abdomen and, as in Arthropods generally, the body is encased in a cuticle of chitin. This, when growth in size takes place (many Insects are hatched out full-sized, *e.g.* the House Fly), necessitates moulting.

Respiration goes on through a series of spirally thickened tubes, the **tracheae**, which, opening to the exterior in all parts of the body except the head, branch in such a way as to carry oxygen all over the system.

The food of Insects is very varied, and the mouth parts vary according to the mode of nutrition. The mouth may be arranged (*a*) for *biting*; (*b*) for *sucking*.

The sexes are distinct, the males being smaller and more decorative. The ornateness of the male in Insects, as in Birds and other animals, may be a factor in courtship, or, alternatively, the more sober appearance of the females may be one of the necessities of maternal life which at times finds inconspicuity an advantage.

Many Insects are parasitic on other animals or on plants, either as adults or during the larval stage, and some, in other ways, are harmful, as when they disseminate the germs of disease or destroy crops; but, on the other hand, the pollination of plants is largely dependent on their activities, while the Honey Bee and the Silkworm (not a worm at all, but the caterpillar stage of a moth) are examples of Insects which may be classed as beneficial to man.

Classification of Insects.—The class Insecta may be divided into the following orders:—

(*a*) **Lepidoptera** (Gk. *lepidos*, a scale, *pteron*, a wing): insects whose wings are covered with small coloured scales which form the "dust" on a butterfly wing, *e.g.* Butterflies and Moths.

(*b*) **Coleoptera** (Gk. *koleos*, a sheath): insects whose fore-wings are useless for flight but form horny sheaths or **elytra** for the two posterior, *e.g.* Beetles and Ladybirds.

(*c*) **Rhyncota** (Gk. *rhynchos*, a beak), or Hemiptera: insects provided with a beak or snout which is a prolongation of the mouth, enclosing lancet-like structures, and is, when not in use, folded under the body, *e.g.* Bugs, Water-Bugs, Lice, Greenfly, Scale Insects, Frog-spit, etc.

(*d*) **Neuroptera** (Gk. *neuron*, a nerve): insects with conspicuous nervures in their wings, *e.g.* May-flies, Dragon-flies, Caddis-flies, Stone-flies, etc.

(*e*) **Orthoptera** (Gk. *orthos*, straight): insects whose posterior wings are folded, fan fashion, in *straight* folds, under the anterior wings, which are stronger in build (though not so hard as the elytra of the Coleoptera), *e.g.* Cockroaches, Grasshoppers, Earwigs, etc.

(*f*) **Hymenoptera** (Gk. *hymen*, a membrane): insects with membranous wings, which when extended are hooked together so that the pair on each side seem to be one, *e.g.* Bees, Wasps, Ants, Gall-flies, etc.

(*g*) **Diptera** (Gk. *di*, double): insects with only two wings, the second pair being degenerate, *e.g.* House Flies, Midges, Gnats, Mosquitoes, etc. The Common Flea, though it has no wings at all, is often placed in this group.

LIFE HISTORIES OF SOME TYPICAL INSECTS

Butterflies and Moths.—**The Cabbage White Butterfly,** *Pieris Brassicae* (Fig. 18).—The **adult insect** or **imago.**—The *head* bears two large compound eyes each made up of many sections or facets. The two antennae are long, jointed and thickened at the tips. The mouth parts form a long sucking-tube or proboscis, which is coiled up like a watch-spring when not in use.

The *thorax* consists of three segments, each bearing underneath a pair of jointed legs which are clawed. From the upper surface of segments two and three arise the two pairs of wings, which are covered with yellow scales overlapping like the slates on a roof. The tips of the anterior wings are black in both sexes, the female having in addition three black spots on the same wing.

The *abdomen* is made up of several segments, but bears no appendages. The whole body is covered with fine hairs. Respiration is by tracheae, and the food consists mainly of the nectar of flowers, absorbed in liquid form through the long proboscis.

Life history.—The female lays clusters of conical eggs on the under side of a leaf, commonly that of a cabbage.

These hatch out in seven to ten days, and out of them emerge the larval forms, the **Caterpillars**.

The Caterpillar (Fig. 18) is a long worm-like creature with a head and twelve visible body segments. The head has no antennae, has tiny eyes, and biting jaws by means of which it cuts pieces from the cabbage leaf.

The body shows little differentiation into thorax and abdomen. Segments 1, 2 and 3 (thorax) bear each a pair of true legs, short structures each ending in a single claw; segments 4, 5, 10 and 11 bear no legs; while the remaining segments bear each a pair of leg-like structures, the **pro-legs**, each being a thick fleshy stump ending in a cushion or pad surrounded with hooks. Respiration is as in the adult, the tracheae opening to the exterior on each side of all the segments except 2, 3 and 12.

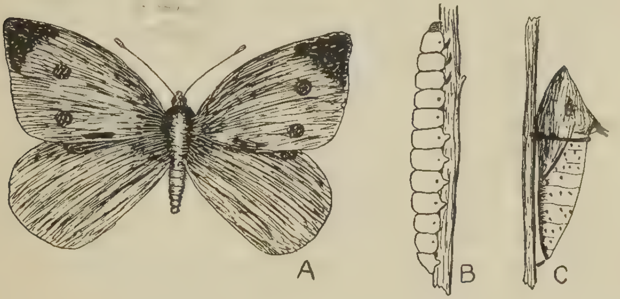

FIG. 18.—Cabbage White Butterfly. A, imago; B, caterpillar; C, pupa

The Caterpillar feeds voraciously, moults several times and, when fully grown, may be about $1\frac{1}{2}$ inches long. It then crawls away to some sheltered place, such as a post or twig, to which it attaches itself by a silk pad at the tail and a silk girdle round its middle. The larval skin splits off and the **pupa** or **chrysalis** (Fig. 18) is revealed. This is a resting stage, during which the creature neither moves nor eats. Within the pupa case the adult insect

complete metamorphis

matures, the wings, antennae and eyes being dimly visible through the parchment-like skin. Finally this skin ruptures and the Butterfly emerges. Somewhat dazed, it spreads its crumpled wings to dry in the sun and, after a few convulsive movements, flits off to begin its brief existence.

Moths.—Moths display a general similarity to Butterflies, but show certain marked differences by which they may be recognised :

1. Their antennae are thread-like, or with a fringe of hairs down one or both sides, giving them a feathery appearance.

2. They fly mostly by night.

3. They hold their wings stretched horizontally when they alight, whereas the Butterfly usually holds them in a vertical position.

4. They pupate mostly in the soil, the pupa case being more rounded in appearance and covered by a silken cocoon.

The **Silkworm Moth** (*Bombyx mori*), which is of such great commercial importance, has a caterpillar which feeds on the leaf of the mulberry but may be reared with equal success on the lettuce. The silk is obtained from the cocoon and is wound off as a continuous thread just as it was produced by the caterpillar. The **caterpillars of Moths** are similar to those of Butterflies, but have usually fewer than five pairs of pro-legs. Some, *e.g.* the **Loopers** (*Geometridae*), have only two pairs, on the ninth and last segments respectively. They get their name from the looping motion by which they progress. These caterpillars, if disturbed, fall from the plant on which they are engaged, leaving, however, a strand of silk by means of which they can regain their former position. If an object, say a pencil point, be placed near the head of such a caterpillar and then drawn away, a silk thread may be found attached. This is strong enough to bear the weight of the animal, which proceeds to climb up towards the point of attachment.

The House Fly (*Musca domestica*).—The **adult insect.**—The *head* bears two compound eyes, three simple eyes and a pair of short antennae. The mouth is a sucking proboscis, and this bears two sensitive feathery palps. The *thorax* has six legs, each ending in a pair of claws and a pad, which exudes a sticky material that enables a fly to walk over a smooth vertical surface such as a window-pane, or to walk head downwards on a ceiling. Like other Diptera, the House Fly has only one pair of wings which are membranous, the place of the other pair being taken by two short "drumsticks," the **balancers** or **halteres**, the function of which is obscure. The *abdomen* is lighter in colour and is made up of six segments without appendages. In the female there is a tube-like structure, the **ovipositor**, which can be protruded from the end of the abdomen and by which the eggs are deposited. The entire body is exceedingly hairy. Food is absorbed in liquid form. A suitable solid, *e.g.* sugar, is moistened with saliva, the resultant solution being sucked up by the proboscis. The sexes are distinct but similar. The male can be recognised by the fact that the compound eyes meet on the top of the head, while in the female there is a gap between them.

Complete Metamorphosis.

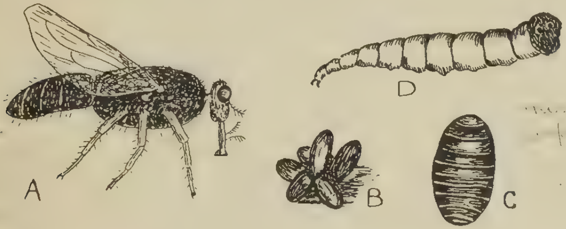

FIG. 19.—House Fly. A, imago; B, cluster of eggs; C, pupa; D, maggot or grub

Life history.—The female by means of the long ovipositor pushes the eggs well into a mass of decaying matter, *e.g.* manure. These eggs soon hatch out, each producing a creamy white legless **maggot** or **grub** which may be looked upon as a sort of degenerate caterpillar. It tapers very much towards the head end, which bears two little grappling hooks. The tail end is broad and has two distinct **spiracles.** The larva absorbs liquid food and in a few days, after two moults, is fully grown. It then pupates in its maggot skin, which shrinks and turns brown, the case of the **pupa** being barrel-shaped. In a short time a trap-door opens at one end and the adult or imago emerges *fully grown.* The small flies also found in houses and believed by many to be young ones belong to another genus, *Homalomya.* The Bluebottle (*Musca vomitoria*) is a near relative of the Common House Fly. The complete life history may, under favourable conditions, be completed in ten days, and within fourteen days from that time the second generation is laying eggs. As each female may lay 1000 eggs the possibilities are enormous and the dangers of this filthy household pest, with its propensities for disseminating disease, are not yet sufficiently recognised.

Bees, Wasps and Ants.—(*a*) **Social types.**—These are perhaps the most interesting members of the Insect group. They have developed the social instinct and live in colonies where there is a division of labour centring round a well-ordered system of household management, in which they exhibit very highly developed instinctive behaviour and even intelligence. They have all been the objects of much careful observation, and good accounts of their life histories and habits are available in many books.

Bees.—The **Honey Bee** (*Apis mellifica*) when domesticated lives in artificial conditions to some extent, but in the natural state forms in holes in trees or walls a nest or hive out of various materials available, *e.g.* leaves, wool, etc. The pieces are cemented together and the crevices stopped up by a resinous material, *propolis*, which the bees collect and elaborate from the resinous materials found in trees, *e.g.* on the buds of the horse-chestnut. The hive contains three kinds of individual:

1. One **Queen Bee**, a female larger than the others, whose sole duty is the laying of eggs, of which she may produce as many as 3000 daily.

2. Several hundreds of males or **Drones**, stouter and shorter than the queen, and possessing no sting. They do no work and of their number only one is chosen to fertilise the eggs of the queen, this act involving his death. Fertilisation accomplished, once for the season, the remainder of the males are slain by the other occupants of the hive and cast forth.

3. Many thousands of **Workers**, smaller than either of the preceding, really sterile females, *i.e.* producing no eggs, their duties being the gathering of nectar for the honey, the construction and filling of the comb, and the care of the developing grubs which hatch out from the eggs.

Life in the hive.—The honeycomb is built up from wax secreted by the workers, and is composed of hexagonal cells which may be used either for storing honey or for housing the fertilised eggs. The majority of the latter produce workers, some laid in slightly larger cells are predestined to become drones, while round the outside of the comb are some specially large **royal cells**, in which potential queens are produced, being fed by their devoted nurses on **royal jelly**, a compound of honey and pollen mixed with saliva. When a young princess is mature the old queen leaves the hive with part of her colony and founds a new colony. This is the process of **swarming**, during which excitement is so intense that the bees forget to sting and may be handled with impunity. The young queen, after her nuptial flight, settles down to the duty of egg-laying and the cycle begins anew.

Wasps.—Wasps are very similar to Bees in their habits. The Worker Wasp has a long tapering abdomen, striped alternately black and yellow, at the end of which is the sting, which differs from that of the bee in being without barbs, so that it can be withdrawn and used again, whereas in the case of the Bee the stinging parts are often left in the victim and the Bee, soon after the attack, dies. The nest and comb of the **Tree Wasp** is a ball-shaped structure built of paper, produced by the chewing of woody material, while the **Common Wasp** builds a similar structure underground.

Ants.—Ants show, like the Social Bees and Wasps, three types of individual in their communities: queens, drones and workers. The mode of life is somewhat similar, but the nesting arrangements are more primitive and the domestic routine seems to entail less labour. They show marked powers of instinct and have long been held up as a pattern of industry. Amongst their many interesting customs are the "milking" of *Aphides* (Greenfly) of a sweet juice which the latter secrete; the keeping as "slaves" members of other species of ants; the harbouring of special Wood-Lice ("Slaters") and other animals which seem to do the scavenging of the nest; and the hospitality shown to various types of beetles.

(*b*) **Solitary types.**—In addition to the Social Bees and Wasps there are many species which are anti-social or solitary, though some have developed the social habit in some degree, *e.g.* Humble Bees. The solitary types build, in various situations, *e.g.* holes or tunnels in the earth, grassy banks, etc., special cells, usually constructed of earth and vegetable matter kneaded into a stiff paste, in each of which they deposit one egg. Along with the egg they place a supply of food material for the use of the grub as it develops, whereupon the offspring is left to fend for itself and the mother departs and probably dies.

Thus the maternal instinct impels her to a self-sacrificing labour of love for the offspring she is destined never to see. In the case of the Humble Bees, all die off except the young queens, which hibernate in sheltered places. Those which survive the rigours of winter found new families in the spring.

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CHAPTER VII

Chordata – 8th Phylum.

VERTEBRATES: INTERMEDIATE FORMS AND FISHES

General characters.—So far the animals dealt with have been Invertebrates, *i.e.* without backbones. The supporting skeleton, if any was present at all, was external. Those which had advanced from the radial symmetry of the Starfish or Jellyfish, and showed a distinct head and tail, foreshadowed to some extent the characters found in the Vertebrates, but with essential differences. The nerve cord was ventral, while the main blood-vessels were dorsal. In the Vertebrates this arrangement is reversed, the nerve cord being dorsal and encased in a backbone, which has thus the double function of protecting the nerve cord and of supporting the body. This backbone arises out of the sheath which surrounds the *notochord*, an elementary rod of supporting material laid down in the early stages of embryonic development. In the Invertebrates respiration took place in water-dwellers by means of rudimentary gills which extracted dissolved oxygen from the water, and in air-breathers through the skin, *e.g.* the Earth-Worm, by a pulmonary chamber, *e.g.* the Snail, or by tracheæ as in the Insects. Amongst the Vertebrates conditions of life similar to those of Invertebrates produce similar methods of respiration: fishes obtain oxygen from the water which surrounds them by means of gills, land animals are provided with lungs, which may be looked upon as highly developed forms of the pulmonary chamber of the Snail, while the Frog, which lives both in air and in water, breathes by lungs and also through the skin. It is an interesting fact that the embryos of all Vertebrates show at an early stage **gill slits** which, as development proceeds, close up and disappear, only one remaining and forming the *Eustachian Tube*, which runs from throat to ear. This seems to show that the gill structures are primitive ancestral characters, and is another piece of evidence that land animals have been derived from earlier types which dwelt in the sea.

Intermediate types.—As has been pointed out (see p. 13), there is a considerable gap between Vertebrates and Invertebrates. A few intermediate types, however, are now known which seem to some extent to bridge the gap. These are:

Balanoglossus—a worm-like animal with some vertebrate characters, *e.g.* a supporting rod or notochord, dorsal nerve cord, gill slits. The animal is found burrowing in sand and mud in the sea.

Tunicates or **Sea-Squirts** (*Ascidians*), which are sedentary marine animals, like fleshy potatoes in appearance. Two openings are present, inhalant and exhalant apertures for a current of water. These animals, which seem akin to the sponges in general aspect, are really degenerate Vertebrates, for their larval forms are tadpole-like, showing quite distinct vertebrate characters.

The **Lancelet** (*Amphioxus*), a small, fish-like animal, two to three inches long, which lies buried in the sand, only the mouth protruding. Through this water is taken in which passes out again through a special opening well back on the under side of the body. From the water so inhaled microscopic organisms and organic debris are extracted.

The **Hag-Fish** and the **Lamprey** (*Cyclostomata* or Round Mouths) are eel-like forms, about two feet long, with round, sucking mouths with which they attach themselves to fishes from which they suck nutritious material. They also feed on worms, crustaceans and other animals. They show an unsegmented notochord and numerous gill slits. The young Lamprey found in streams is often known as "nine-eyes" because of these rows of gill openings, which appear like a series of eyes.

FISHES

Fishes, although showing a high stage of development, are placed low down in the scale of vertebrate animals because some of their characters are of a primitive type. They show special adaptations to aquatic life. They breathe by gills, are so shaped as to facilitate rapid movement through the water, and display a remarkable fertility in reproduction, a character correlated to the enormous risks run (*cf.* Plants generally). They show little in the way of external protection, though some extinct types, and the Sturgeon of to-day, specialised in a covering of bony plates. They depend upon the keenness of sight and other senses, and upon swiftness of movement to escape their enemies. The strong, muscular tail is the main organ of locomotion, the paired fins (akin to the limbs of higher animals) and the single unpaired fins being mainly used for balance.

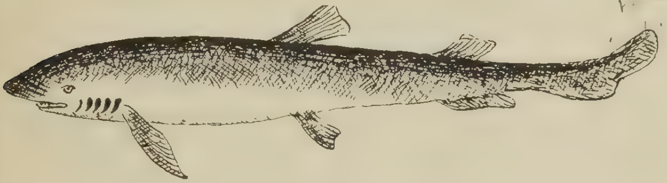


FIG. 20.—The Dog-Fish. Note the position of the mouth and the open gill slits

Kinds of Fishes.—The two main classes are:

1. **Sharks**, **Dog-Fish** (Fig. 20), **Skate** (Fig. 21) (*Elasmobranchii*). Here the gill slits are separate and uncovered.
2. **Ordinary Fishes** (*Teleostii*), including all the common

type, *e.g.* Cod, Haddock, Herring, Salmon, Trout, Eel, etc. These have the gills covered by a lid or **operculum**.

The **Trout**, *Salmo fario* (Fig. 22), will serve as well as any other for general description and study. Its development can be carried out from the egg stage in a simple tank provided with running water. The Herring and the Haddock are very similar to the Trout in most of their characters and are often more easily obtained. The fins in various fishes show differences in arrangement, *e.g.* in the Whiting the pelvic fins are in front of the pectorals.

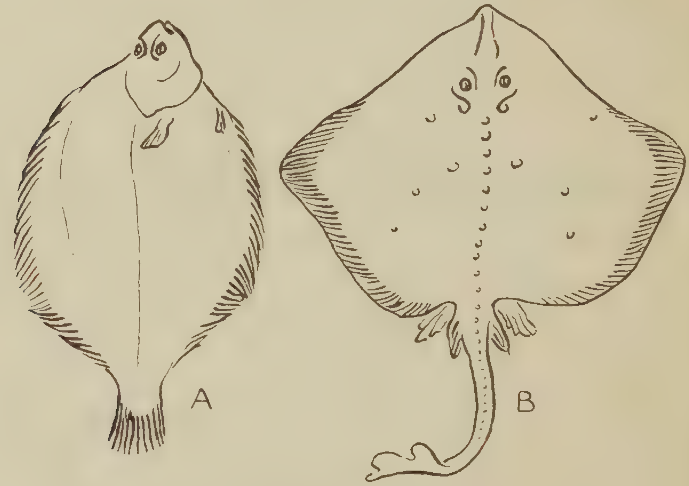


Fig. 21.—Flat Fishes. A, Plaice; B, Skate

External characters.—The torpedo-like body is well adapted for rapid movement in the water. The tail is broad and symmetrical, and is operated by powerful muscles which completely fill the rear part of the body. There are two pairs of fins on the under side of the body: the **pectoral fins** (L. *pectus*, *pectoris*, the breast), behind the head, and the **pelvic fins**, situated farther back and in front of the **vent**, where openings from the intestine, the sexual organs and the kidneys are found. There are two **dorsal fins** (unpaired), and, just behind the vent, a single **ventral** or **anal fin**. All the fins, including the tail, are supported by bony rods or **fin-rays**.

The **head** is bluntly conical, has a transverse mouth and two lateral eyes. Each eye is covered completely by a transparent skin, there being no eyelids, so that the fish cannot close its eyes. In the fore part of the snout are two **nostrils** which do not communicate with the mouth cavity but end blindly. They are not used for respiration, and their function is probably to test the quality of the water. **Ears** are present but are entirely internal.

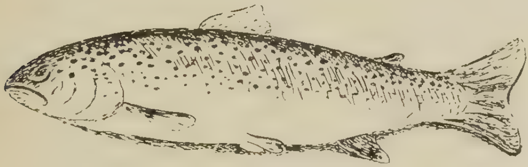


FIG. 22.—The Trout

The **skin** is silvery, but coloration depends to some extent upon the nature of the habitat, *e.g.* trout found in peaty water are dark in colour. The surface of the skin is covered with fine scales which overlap like the slates of a roof. Each scale is more or less circular and grows in size by the addition of rings of calcium carbonate. Hence the number of rings is an indication of the age of the fish. Black, red and yellow spots are characteristic of the trout. Along the middle of each side of the fish is a **lateral line**, which is provided with sensory cells.

The Gills.—Behind and below the head are the gills, which serve for respiration. An extension backwards from the head forms the **operculum** or gill cover. The posterior edge of this can move out and in, thus opening or closing the **gill chamber**, which contains four **gill slits** communicating with the mouth cavity. Bordering these gill slits are reddish, comb-like structures, the **gills**. These appear red because of the numerous blood-vessels which come very near the surface of the membrane covering the gills. Through this oxygen is taken in and carbon dioxide given out. The fish takes in water through the mouth. This passes over the gills and so to the exterior through the openings made by the opercula. These rhythmic movements of mouth and opercula may be easily followed in the living fish.

Internal structure.—The bony, lipless mouth has teeth along the edges of the upper and lower jaws, and, in addition, there are teeth on the roof of the mouth and on the tongue. The mouth leads through the **gullet** to a U-shaped **stomach** with which are associated a reddish-brown **liver** and a green **gall bladder**. Following the stomach and ending in the anus is the **intestine** or gut. At the point where it joins the stomach a number of blind tubes are given off which probably secrete digestive juices, as does the liver, which produces **bile**. This is stored up in the gall bladder, whence it passes into the upper part of the intestine.

Along the upper wall of the body cavity lies a sac-like **swim bladder**. This is filled with gas secreted by the blood and probably serves to increase the buoyancy of the fish. It should be noted that the centre of gravity of the fish is above the middle line, *i.e.* the upper part of the body is heavier than the lower, so that if the balancing fins be cut off, or when the animal dies, the body floats belly upwards. Behind the swim bladder is the **kidney**. This extracts certain waste products from the blood (*cf.* the nephridia of the Earth-Worm) and passes them to the exterior at the vent through a narrow tube, the **ureter**.

The **heart** lies in the forward part of the body cavity (separated by a partition from the rear part which contains the viscera), and consists of two chambers only, a muscular **ventricle** and a thin-walled **auricle**. Impure blood is received by the auricle, and passes to the ventricle, which by its rhythmic pulsation drives it forward to the gills.

In the male there are two spermaries containing the **milt** or "soft roe," while in the female there are two ovaries containing the innumerable eggs or "hard roe." In both cases these organs open to the exterior at the vent between the anus and the ureter. In the case of the Trout the eggs are laid on the gravelly bottom of the stream, the male sheds the milt consisting of sperms on the top of the eggs and fertilisation results. The eggs remain sunk while development goes on. The eggs of the Herring also remain sunk, whereas those of the Haddock float on the surface of the water.

In some fishes, *e.g.* the Skate, the **skeleton** is cartilaginous, but in fishes generally this cartilage becomes ossified or bony. The skull is a complicated structure made up of numerous bones. Within the cavity of the skull lies the **brain**, stretching back from which is the **spinal nerve cord**. This passes through and is protected by the **vertebrae** or bone units which make up the backbone. These vertebrae are of two kinds. Those in front bear ribs which enclose the body cavity, while those farther back have the ribs replaced by a single spine extending downwards and similar to the spines which all the vertebrae have on their upper surfaces. In addition to the ribs there are, attached to the vertebrae, intermuscular bones which curve upwards.

Life history (Fig 23).—The egg is enclosed in a tough membrane and contains a pink yolk, *i.e.* a store of nutriment for the developing embryo (*cf.* the endosperm of seeds). At one pole of the egg is the formative protoplasm which by successive divisions produces the embryo trout.

At an early stage two black spots appear—the eyes. In about forty days the embryo, which hitherto has been curved round the yolk, straightens out. Gradually the yolk sac decreases in size, being finally completely absorbed. During this process of rapid growth the buoyancy of the yolk causes the young fish to float back downwards. In about a year the young trout is about three inches long and is in every way, except for size, like its parents.

Some common fishes.—The **Salmon** is a near relative of the Trout. Though it spawns in fresh water, it spends most of its time at sea, where it feeds on herrings and other fishes, on small crustaceans and marine worms. In the *Memorandum on Nature Study* (Scottish Education Department) Professor J. Arthur Thomson says:

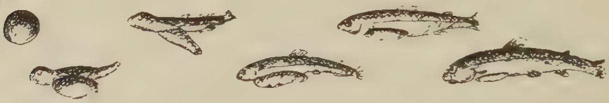


FIG. 23.—Development of the Trout. Note the gradual disappearance of the yolk sac.

"The eggs are laid in the winter months in the sandy and gravelly bed of the stream by the female salmon and fertilised there by the male salmon. The eggs have many enemies, and many perish. Those that survive develop very slowly, taking three to four months to hatch.

"At first the young ones are very sluggish and lie among the stones, living on their legacy of yolk, which may last for fifty days. As the yolk becomes exhausted they become more active, and about eight weeks after hatching (*i.e.* in spring) the fry are about an inch long. They now grow quickly, feeding on minute creatures in the water, and by the end of a year they are somewhat trout-like 'parr,' about four inches long.

"In the second or third spring after their birth they put on their silvery 'sea-jacket,' are about seven inches long, and descend to the sea as 'smolts.' In the sea they feed voraciously, *e.g.* on young herrings and haddocks, and on the eggs of crustaceans, and grow large.

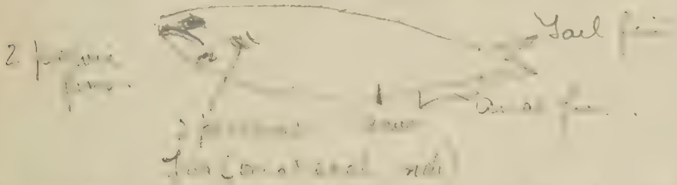
"In fifteen to eighteen months or more they return to the rivers as 'grilse,' perhaps two to five pounds in weight, and they are able to spawn. Thus the story begins again. After spawning the salmon are out of condition and have to return to the sea to regain their full vigour. It may be safely said that most, if not all, of the mature salmon's energy is accumulated during the time it spends in the sea. Although they develop slowly, they grow quickly and they may live to a good age, attaining a weight of fifty to seventy pounds in very fortunate cases.

"Attention may be directed to the colour-changes in the course of the life history and in the course of the year, to the gymnastic feats of leaping, to the combats of the males, to the numerous risks that beset the salmon at various times, to the fact that they sometimes return to the same river, and so on. The life history of the salmon should be contrasted with that of the flounder, the eel, the lamprey and others."

The Eel.—The Eel has an elongated, snake-like body, with only the pectoral paired fins and a single continuous unpaired fin extending along the back and the ventral surface. The animal bores in the sand and mud and can swim rapidly by an undulating motion of the body. The life history is interesting. The eel found in streams and ponds does not breed there, but makes its way down the stream and goes out to sea, to, it is believed, the Continental Shelf which gives a region of shallow water to the west ~~of Britain~~. There the eggs are laid and fertilised. The young eels or "elvers," a few inches long, swarm up the rivers, and many finally may reach ponds which seem to have no connection with such streams. There they grow in size and reside for some years. Finally they return to sea, lay their eggs and probably die—at least they are not known to return to an inland life.

Flat Fishes (Fig. 21), *e.g.* Plaice, Sole, Flounder, Halibut, are found in sandy and gravelly shores. In the young stage they are normally shaped and upright, but they take to lying on their sides and gradually the eye shifts round permanently to the upper side (usually the right side). The under side of these fishes is usually white, while the upper side shows a coloration which blends with the sea-bottom and makes them inconspicuous. Such fishes are flattened from side to side, while the Skate is flattened from above downwards.

The fish is almost just a large muscle. The [illegible] as [illegible]. By moving the muscle [illegible] forward. [illegible] the fins are steering purposes. The fins are delicate skin on supple bones. They are [illegible]. One [illegible] fin (median) [illegible] on its back is the dorsal fin. Sometimes [illegible]



The most [illegible] like [illegible] fin. In the [illegible] fin. [illegible]

[illegible]

In many [illegible]

[illegible] different — [illegible]

a little beard - the barbule. Cod has
a big one. These are sensory apparatus.
Get oxygen from water. Water taken in by
mouth. Is passed over gills & flung out by
gill slits. Some fishes have a flap over
the gill slits. Haddock has. A gill cover
in haddock. They are floating fish in water.
The gills are richly supplied with blood
vessels by minute gills (the) there are little
act as filters. A barrel shaped fish is
the same colour on each side after they are
not the same colour all over.
Flat fish have stripe colour on top &
light underneath. Floating fish are the
this way as looking from up you
see them against the ground of sea. From
underneath you see them against the light.
Barrel shaped fish have same thing
- colour dark on top - light underneath.
Some fish change colour for their Others
migrate etc. It all depends on food
Some come from salt water to
fresh to lay eggs (Salmon

CHAPTER VIII

AMPHIBIANS AND REPTILES

Amphibians (Gk. *amphi*, double, *bios*, life). — The name suggests the double phase exhibited by these animals in their mode of life as adults, or, at least, in their life history. They are hatched from eggs laid in the water, spend their larval stages in that element, and during this period are in their general characters very much akin to fishes. After a gradual metamorphosis they may take to a land life and breathe by lungs, though as a rule they never go far from water and return to it during the spawning season. The group includes Frogs, Toads and Newts.

The Frog (Fig. 24).—The Common Frog (*Rana temporaria*) is a familiar object, can be kept in captivity in suitable conditions and, in spite of general antipathy, may be handled with impunity.

External features.—The head, somewhat flattened and triangular, is continuous with the body, there being no neck. There are two **nostrils** which open into the mouth cavity, two eyes with rudimentary eyelids and in addition a third eyelid or **nictitating membrane** which can be drawn upwards over the eye. Behind the eyes and nearer the under side of the head are two darker spots, flush with the general surface, the **ear drums**. Each consists of a membrane stretched over the aural cavity. At the posterior end of the body is the **cloaca**, a common vent for the intestine, the ureters and the sexual organs.

The **limbs** consist of two fore limbs each provided with four digits and the two hind limbs which have five long webbed toes. No nails or claws are present on any of the digits. The hind limbs are much longer and more powerful than the fore limbs, being used for swimming, and for jumping, which is the characteristic mode of locomotion on land.

The **skin** is moist and smooth and is loosely attached to the body, there being under the skin many **lymph sacs** which contain fluid. The whole skin is kept moist by many glands which secrete the necessary fluid. The coloration is variable, depending to a considerable extent on the light or shade in which the animal for the time lives, a change in background or amount of illumination giving rise to a corresponding change in the intensity of colour.

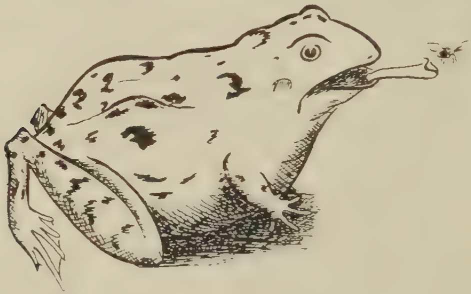


FIG. 24.—The Common Frog

Internal structure.—The **mouth**, owing to the fact that the bones of the jaws are cartilaginous and loosely jointed, is capable of an extraordinary gape. **Teeth** are present on the upper jaw but there are none on the lower. The **tongue**, which is large and muscular, and provided with a forked tip, is attached not at the back of the mouth but at the front of the lower jaw, and can be rapidly flicked out, being used for the capture of insects, which adhere to its sticky surface. The **alimentary canal** consists of a gullet or oesophagus, a stomach leading into the small and large intestines and having associated with it the liver and the pancreas, both of which secrete digestive juices.

Respiration takes place through the nostrils. The floor of the mouth is depressed and air rushes in through the valves in the nostrils. These then close, the floor of the mouth rises and the enclosed air is driven through the **glottis**, a slit in the floor of the mouth leading into the lungs. The outward process of **expiration** is brought about by the contraction of the lungs, which have been forcibly expanded by the pressure set up during **inspiration**.

The **sexual organs** are, in the male, the **testes**, which produce spermatozoa, and, in the female, the **ovaries**, in which the ova or egg cells arise. In both cases the sexual products pass out through the cloaca. The **heart** is a muscular organ consisting of three chambers, two **auricles**, one receiving pure blood from the lungs, the other impure blood from the body. Both auricles contract at once and the two kinds of blood pass into the single **ventricle** together, the arrangement being such, however, that when the auricle contracts most of the pure blood goes to the body and most of the impure blood goes to the lungs.

Life history (Fig. 25).—After the winter **hibernation**, when all activity is suspended, the animal apparently breathing through its skin and not by the lungs, the frogs take to the water, in which the female lays her thousands of eggs, over which the male immediately sheds a milky fluid containing the spermatozoa. Each egg is surrounded by a transparent jelly which in the water swells up enormously and acts as a protective envelope. A sperm passes through this and fertilises the female unit which, with a small amount of yolk, lies within the egg. Development of the egg produces a **tadpole**, and this after gradual metamorphosis becomes a young frog. The stages in development may be followed if some ova are kept in water in which there are some water-weeds. The chief stages may be summarised as follows :—

1. The black centre of the egg becomes oval and elongated. After a time it makes its way through the jelly. Eyes are present but no mouth, and respiration must be through the skin.

2. The tadpole attaches itself to some water-weed by means of a cement gland in the forward part of the head.

3. The mouth, provided with horny jaws, develops, the coiled intestine becomes visible through the skin, and the animal begins to feed on the water-plants. They will, however, eat meat and also their dead companions.

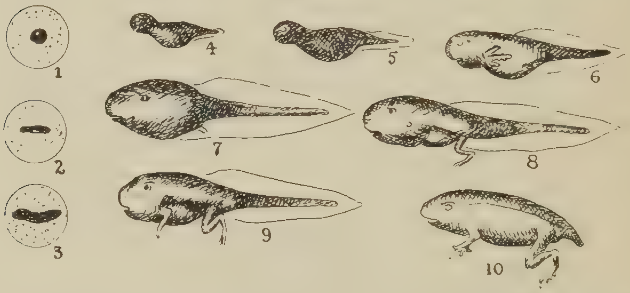


Fig. 25.—Development of the Frog: 1-3, the egg showing first stages before hatching; 4, 5, tadpoles soon after hatching; 6, tadpole with mouth and external gills, with growing operculum; 7, tadpole showing spout on left side, and the vent; 8-10, successive stages showing development of the limbs and gradual absorption of the tail

4. Three pairs of external gills appear on the sides of the head.

5. These disappear and give place to internal gills covered by an operculum, and bordering four gill slits which open from the mouth cavity to the exterior. Water passes in at the mouth and out by a single aperture or spout on the left side.

6. The hind limbs become visible and gradually increase in size.

7. Meantime the fore limbs are developing under the operculum in the gill chamber, the lungs begin to function and the tadpole comes to the surface for air.

8. The gills cease to function and the fore limbs burst through the opercula.

9. The tadpole seems to fast for a time, living probably on the material in its tail, which decreases in size.

10. The animal hops out on to land a young frog, the remains of the tail being still visible.

The Toad.—The Toad is very similar to the frog. Its skin is darker and covered with warty outgrowths. Its hind limbs are not so well developed as those of the frog, being used more for crawling than jumping and, as the toad is not so dependent on water, less for swimming, the webbing of the toes being less marked. The spawn is laid in long strings of gelatinous material in which the eggs are embedded. These strings are deposited amongst water-weeds, with which they become entangled. The toad, "ugly and venomous," has some poison in its skin but may be handled without fear, and is a useful visitor to the garden, as it feeds on slugs and insects which are harmful to plants.

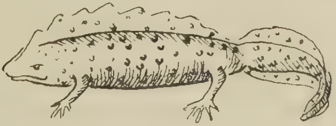


FIG. 26.—The Crested Newt

The Newt or Eft (Fig. 26).—The Newt is an amphibian common in our ponds. The development from the egg is very similar to that of the frog, external gills being present for a time on the tadpole. The tail, much flattened from side to side, persists, and the limbs are adapted for movement on land, where the animal feeds on insects, worms, snails, etc. The male of the Common Newt develops a crest along the back, and in another species, the Crested Newt, which is not so common, both sexes bear these dorsal outgrowths The Common Newt is about three inches long and has a smooth skin, while other species may be larger with a warty covering. Belonging to the same group as the newts is the Salamander, which is not found in Britain. It is viviparous, *i.e.* the eggs hatch out within the body of the female and the young emerge alive.

Reptiles (L. *repo,* I creep). — The Reptiles, as we know them to-day, are the remains of a great group of Vertebrates which first took wholly to a land life. While the Amphibians at some time in their development breathe by gills, the Reptiles never do. Many fossilised remains of extinct reptiles are known, and from these, by a process of reconstruction, fairly clear ideas have been obtained of the nature of these huge and ungainly animals. Amongst these are *Plesiosaurus*, some forty feet in length ; *Ichthyosaurus*, about the same size ; *Brontosaurus*, a Dinosaur nearly sixty feet long ; and the *Pterodactyl*, a bird-like reptile which had the power of flight by means of wings which might be twenty feet from tip to tip. In spite of, or perhaps because of, their huge size and their formidable equipment of armour-plate, these animals failed in the struggle for existence, their places being taken by lighter, swifter and more adaptable forms of life. The modern representatives of the group are Tortoises, Lizards, Snakes and Crocodiles.

Tortoises and Turtles.—Here the animal is encased in a carapace or shell consisting of bony scales which originated in the skin. *Tortoiseshell* is a well-known article of commerce. The Tortoise is a sluggish, slow-moving animal, and, like all reptiles, cold-blooded, *i.e.* the blood assumes the temperature of its surroundings. The animal may be kept in captivity, feeds on lettuce and other vegetable material, may live for fifty years, and hibernates during the winter. It lays eggs which are provided with hard calcareous shells.

Lizards (Fig. 27).—The Common Lizard (*Lacerta vivipara*) is found throughout Britain, preferring sunny, sandy or rocky situations. It feeds on snails, worms and insects, and hibernates during the winter. The animal is about six inches long, the body being covered with stout scales. The limbs present a somewhat sprawling appearance owing to the arrangement of the bones. The tail is peculiarly brittle and is readily shed. Lost tails, and even legs, may be regenerated. This species is viviparous, *i.e.* the young are born alive, but many other lizards are oviparous.

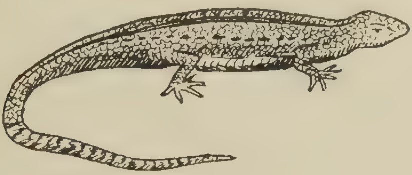


FIG. 27.—The Common Lizard

The *Slow-* or *Blind-Worm* (Fig. 28), which is neither slow nor blind, and neither worm nor snake, is a lizard which possesses no limbs. It may be a foot in length, the rear half being tail, and this, as in lizards generally, is readily shed. The position of the transverse cloacal slit marks the end of the body and the beginning of the tail, and this aperture in the Slow-Worm is half-way along the body. In Snakes the cloaca is near the posterior end of the body, *i.e.* the animal has a very short tail region. The animal is quite harmless and feeds on worms, snails, etc. The eyes have movable eyelids which close when the animal dies, hence probably the name "Blind-Worm," which is quite a misnomer, as the animal is provided with quite obvious eyes. The tongue is forked and, as it is constantly being darted forth in the process of feeding, there is a mistaken conception that the animal "stings."

Snakes.—Snakes are specially abundant in warm countries, but several are found in Britain, *e.g.* the *Grass Snake*, which may be three feet long and is harmless, and the *Adder* or *Viper* (Fig. 28), which is commonly less than two feet long and gives a poisonous bite, which, however, is seldom fatal. The Adder is distinguished by a dark zigzag stripe along the back and has a flattened head. The tongue is forked, but this is in no sense a sting. The "bite" is effected by two hinged teeth or "fangs" in the upper jaw against which they lie when not in use. Each fang has a groove down which the poison flows from a special poison gland in the roof of the mouth. It is said that the bile of a Snake is an antidote to the poison, and as the poison is used in killing other animals for food, some such arrangement, in the interests of the animal itself, would seem to be necessary. The internal organs are peculiarly elongated, one lung is much smaller than the other or may be absent, the liver is long and narrow and the kidneys are not opposite one another. The heart is three-chambered and goes on beating long after the animal has been killed. A hasty dissection of any specimen found will well repay the trouble taken, the interior being specially beautiful and

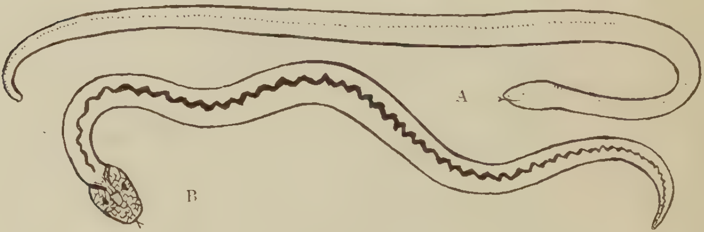


FIG. 28.—A, the Slow-Worm ; B, the Adder

interesting. The Adder is viviparous, though most snakes are oviparous.

Crocodiles and Alligators. — These are large reptiles which can swim by means of their powerful tails but spend most of their time lying on the mud in water just deep enough to cover them, only the tip of the snout bearing the nostrils remaining above the surface. Alligators are confined mainly to America and differ from Crocodiles in having shorter and broader heads. Both are oviparous. The eggs are of considerable size (about three inches long) and are laid in the warm mud, where they hatch without further attention.

Crocodiles display an interesting case of partnership or symbiosis. A little bird associates with them and keeps the skin clean from parasites. In return the bird is protected by the Crocodile and, according to a Greek writer, is allowed to "pick the reptile's teeth."

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CHAPTER IX

BIRDS

Birds, in the complexity of their structural characters and in the stage of development of the higher qualities found amongst living things, show a high degree of advancement, and except in brain development are entitled to rank with the Mammals in the ascending scale of evolution. They are not nearly related, however, to Mammals, their line of descent having diverged at an early period. In many ways they show kinship with the Reptiles, which, as we have seen, foreshadowed the possibilities of flight amongst Vertebrates. In courtship, in nest-building, in care and education of the young, and in their apparent *joie de vivre*, they show emotional and intellectual qualities of a high order.

The earliest bird of which the geological record has any information is *Archaeopteryx*, whose fossilised remains have been found in the slates of Bavaria. It seems to have been about the size of a Crow, had jaws provided with teeth, and a long tail with twenty vertebrae. The modern bird has no teeth and practically no tail (skeletal), while the structure of its wing bones is of a simpler and more rigid pattern than is exhibited by this early ancestor.

General characters.—The **feathers** of the bird are horny outgrowths of the epidermis, each arising around a small papilla or protuberance. These papillae are found not all over the skin but in definite feather tracts (*pterylae*), which are separated by bare spaces (*apteria*). In some birds, *e.g.* the Sparrow and the Thrush, these feather tracts are narrow, while in others, *e.g.* the Pigeon and the Duck, these areas are comparatively broad. Feathers are of three kinds:

(a) *Contour Feathers*, those which form the outline of the body.

(b) *Down Feathers*, small fluffy feathers lying underneath the contour feathers in many birds, *e.g.* Hawk, Eagle, Duck, Swan.

(c) *Filoplumes*, the long straggling hair-like feathers which have to be singed off after a bird has been plucked.

A **contour feather** consists of a central axis, consisting of a lower bare part, the **calamus** or **quill**, and an upper part, the **rachis** or **shaft**. At right angles to the latter are the **barbs** which, held together by a series of scrolls and hooks, the **barbules**, form the **vane** or **web**. At the base of a contour feather a similar but usually smaller feather arises, whose function is unknown, the **after-shaft**. In some birds, *e.g.* the Pheasant, these secondary feathers are quite large, while in the great flight feathers of the wing and tail of all birds such after-shafts are never found. In birds which do not fly, *e.g.* the Ostrich, the barbs are free, the barbules not being interlocked. A bird's feathers are dressed with an oil secreted by the **preen gland**, situated above the root of the tail.

Skeleton.—The bones, though strong, are comparatively light, many containing within them air sacs which are in communication with the lungs. Similar air cavities are present in other parts of the body, so that a good supply of respiratory air is always present, this being a necessity on account of the rapid and prolonged movements of birds. The **neck** is very flexible, there being from twelve to twenty-four vertebrae. In Mammals there are only seven neck vertebrae, this being a constant number, even in such different types as the Whale and the Giraffe. The neck of a bird is attached to the head by a ball-and-socket joint, there being on the base of the skull only one boss or *condyle*, whereas Mammals have two.

The **fore limb** (Fig. 29) is similar to our own, except for the hand. There are only three digits, the thumb and two fingers. The thumb is a mere stump which bears four feathers (*the bastard wing*) and sometimes a claw. The two fingers are welded together to form a double rod, the second finger being much reduced. The wrist bones are fused and there are no joints to the digits, so that a very rigid framework is produced, suitable for flight. The flight feathers of the wing are attached, some to the fore-arm, the remainder to the bones of the hand, the spaces between the feathers being covered in part by smaller feathers known as **coverts**. The **breast-bone** or **sternum** and the bones of the shoulder girdle have undergone great changes to support the muscles of flight. In most birds the sternum has a prominent midrib or **keel** for the attachment of muscles, while in birds which fly little or not at all this prominence is slight or absent.

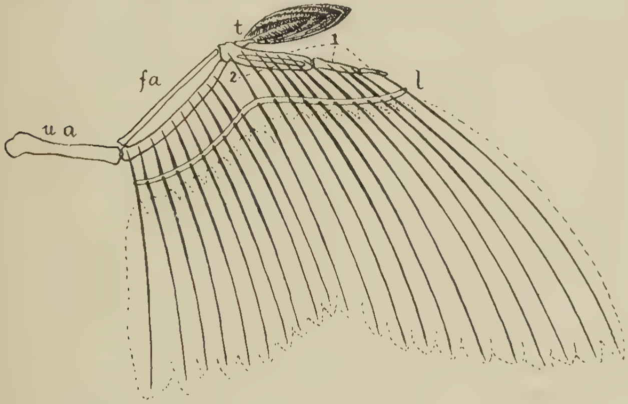

FIG. 29.—Diagrammatic sketch of a bird's wing: *t*, thumb; 1, first finger; 2, second finger; *f a*, fore-arm; *u a*, upper arm; *l*, ligature which binds the quills together

The **hind limb** is like the human leg, the knee, however, being within the body. The visible joint is the ankle. The various bones of the foot have become welded together and form what we call the "leg" of the bird, which therefore walks on its toes. Of the original five toes only four remain, and these display an arrangement which depends on the mode of life of the possessor.

The Alimentary System. — Birds have no teeth and cannot masticate their food, which passes directly into a dilated part of the gullet known as the **crop**. Here it remains for a time and is moistened by glandular secretions. It then passes to the stomach, which consists of a fore part, the **proventriculus**, in which digestive juices are mixed with the food, and an after part, the **gizzard**, which is provided with thick muscular walls lined with a horny substance. Here the food is ground up by muscular movements, the process being assisted by small stones which are swallowed by the bird. The food then passes to the intestines, useful matter being absorbed, waste material being ejected through the cloaca, where, as in the fish, the intestine, the duct from the generative organs and the ureter from the kidneys end side by side.

Other organs.—The **lungs** are well developed and give off diverticula or air sacs. The **heart** is four-chambered. Impure blood from the body passes to the right auricle and so to the right ventricle, which pumps it to the lungs. The purified blood returns to the left auricle and is then, by the contraction of the left ventricle, driven to all parts of the body. The circulatory system is essentially much the same as that of Mammals, but the pulse is higher (120 beats per minute during rest, much more during flight), and a higher temperature is normally found in birds. During brooding the blood-vessels of the abdomen become much enlarged and provide the heat required for the hatching of the egg.

The **eye**, which is very efficient, has in addition to two movable eyelids a third one or **nictitating membrane** which is frequently drawn over the eye, thus keeping it clean. Behind the eye and rather lower is the opening of the ear, invisible from the outside. The hearing of birds is very acute.

Reproduction.—Spermatozoa are passed from the male to the female and the eggs are fertilised, either in the ovary or as they pass down the oviduct, before they are surrounded by calcareous shells.

Within the shell there is a double membrane, the two layers of which separate at the broad end of the egg to form an air space. This space grows larger as time goes on and, as we know from experience, is some indication of the freshness or otherwise of the egg. Within these membranes is the albumen, the *white of egg*, in which lies a sphere of yolk and the associated embryo, the whole mass being kept in position by two twisted cords or **chalazae**, one at each end of the egg. The yolk serves for the nourishment of the embryo, air for respiration being provided from the air space already mentioned.

After the lungs begin to function the chick breaks the shell by means of its beak and "steps out into the world." The young of some birds are naked and comparatively helpless when born, so that a great deal of parental care is necessary, while in other cases, *e.g.* Common Fowl and Duck, the infant birds are clad in downy feathers and are able to feed themselves from the first.

Adaptations to environment and mode of life.—Mention has been made of the structural adaptations of the wing, of the respiratory air mechanism and of the alimentary system. Birds which spend most of their time on the wing, *e.g.* the Swift, have long powerful wings, while those whose habits entail little or no flying have the wings comparatively small and weak. The Penguin, which lives mainly in the water, cannot fly at all, its wings being so modified as to form fins by which the animal swims.

The **jaws** of birds (Fig. 30) show many different forms correlated to the nature of the food and the method of obtaining it. Birds which feed on seeds, *e.g.* the Finches, have strong conical beaks by which such seeds can be crushed. Carnivorous birds, such as the Hawks, have hooked beaks, which are efficient tearing instruments, while fish-eaters, like the Heron, the Kingfisher and the Solan Goose or Gannet have dagger-like beaks, the horny interiors being thrown into tooth-like projections. Birds which probe in the mud for their food have long narrow beaks, *e.g.* Snipe and Woodcock. Here the upper jaw is provided with a sensitive tip which can be moved independently of the rest of the beak, so that suitable objects can be located and grasped below the surface. Insectivorous birds, *e.g.* Swift, Swallow, Nightjar, which capture insects in the air, have short beaks with wide gapes and are provided also with sticky tongues.

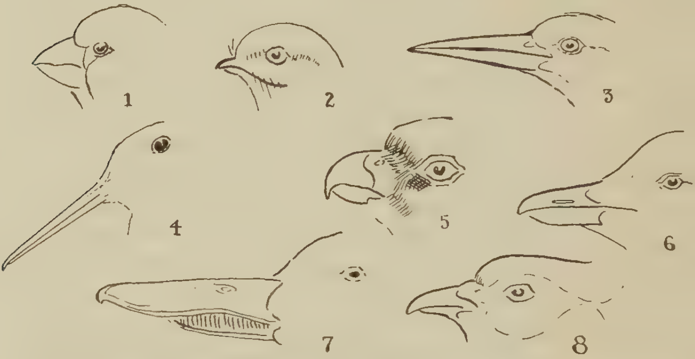

FIG. 30.—Types of beak: 1, Hawfinch; 2, Nightjar (wide gape); 3, Kingfisher (fish-eater); 4, Snipe; 5, Hawk; 6, Seagull; 7, Shoveler Duck (has straining-plates, *cf.* Whale); 8, Pheasant

Legs and feet (Fig. 31) similarly show great variations.

Wading birds, *e.g.* Curlew, Whimbrel, Redshank, have long legs as well as long beaks, and have also long, well-spread toes suitable for walking in mud. Most swimming birds have webbed toes, *e.g.* Duck, Swan, while some good swimmers, *e.g.* Water-Hen, have separate toes. The Coot and the Grebe have lobed toes. Most birds have the toes arranged three in front and one behind. Climbing birds, *e.g.* Woodpecker, Parrot, have two in front and two behind, while the Swift differs from the Swallow and all perching birds in having all four toes directed forwards.

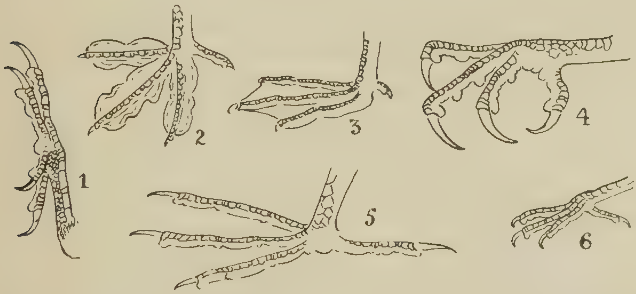

FIG. 31.—Types of feet: 1, Woodpecker; 2, Coot; 3, Duck; 4, Eagle; 5, Heron (wading bird); 6, Thrush (perching bird)

Migration of Birds.—As is well known, many of our British birds are resident all the year round, while others are with us for only a part of the year, some being Winter and others Summer Visitors. The reasons for such migrations are probably connected mainly with the food supply rather than with climate, although that is an indirect factor. Birds, for example, which live mainly on insects must in our winter go to warmer regions where insects still abound, while our Winter Visitors come mainly from the frozen north where supplies of food are no longer available. Hence the migration routes lie mainly north and south, and much information has been gained by patient observers at suitable points on these routes. Another source of information is the marking of nestling birds with aluminium rings giving time and place of origin. Some of these are ultimately sent by the finders back to the source, and thus a definite record is possible of the extent and direction of the bird's wandering, *e.g.* a Swallow marked in this country has been picked up in South Africa.

The mysterious instinct which causes such birds to move off in organised bands and to come back again, sometimes to the old nest even, is little understood. How they find their way (*cf.* the Homing Pigeon), how they are impelled to migrate while food is still obtainable, why, in some cases, the males travel first and alone, and why it is that the young birds in many species leave first, are some of the many interesting problems which the subject presents. Certain it is that birds cover great distances at incredible speed, often arriving at their destinations in an exhausted condition. Pycraft in his *History of Birds* quotes Herr Gätke, who spent a lifetime in the study of birds, as believing that "the little Arctic Bluethroat could leave Africa at dusk one evening and arrive in Heligoland nine hours later, having travelled 1600 geographical miles in a single night at the astounding velocity of 180 miles per hour!" According to another estimate of his (Gätke's) Curlews and other birds traversed a distance of four miles in one minute, *i.e.* at the rate of 240 miles per hour. Pycraft also gives the known case of a Carrier Pigeon which has "maintained a speed of fifty-five miles for four hours in succession" and is inclined to think that "it is extremely unlikely that this is much, if at all, exceeded by wild species during long-distance flights."

Amongst the **Summer Visitors** which may be looked for are the Swallow, Martin, Swift, Cuckoo, Corncrake, Nightingale (south of Britain); amongst the **Winter Visitors** are the Fieldfare and Redwing (kinds of Thrushes), the Woodcock, Jack Snipe, numerous Ducks and some Geese; while the chief **Birds of Passage** are wading birds such as the Whimbrel and the Sandpiper. Various other stray migrants are found from time to time, such as the Stork, Crane and Sand-Grouse.

CHAPTER X

MAMMALS

Mammals (L. *mamma*, the breast) are animals which feed their young by milk and include the most highly developed members of the Animal Kingdom. The word animal, like the words insect and reptile, is often used in a mistaken sense as the equivalent of mammal, but while all Mammals are animals, the majority of animals belong to other groups, such as Molluscs, Insects, Birds, and so on. Mammals excel in brain development and in the concomitant possibilities of reasoning powers and of the emotions, both of which reach their climax in man. The organic connection, as well as the post-natal association, between mother and young is prolonged, and the self-sacrificing devotion of the parents may have had much to do with the evolutionary success of this great group.

The complex **skeleton** shows much in common with that of other Vertebrates, such as Reptiles and Birds, and has the same general plan, being modified, however, in the different races for the special needs of their modes of life. Just as the "hand" of the Bird shows adaptations for flight, so the "hands" and feet of Mammals, made up of the same skeletal elements, show many modifications called forth by environmental and other necessities. The normal five fingers may be reduced in number to, for example, four in the Pig, three in the Rhinoceros, two in the Cow and one in the Horse In the Whales and Porpoises, land animals which have gone back to an aquatic life, the hind limbs have disappeared altogether, the fore limbs being turned into stiff paddles or fins, the four (sometimes five) digits being bound together under one epidermal covering.

The **heart** is four-chambered, as in Birds, pure and impure blood being thus perfectly separated. All Mammals breathe by **lungs**, these and the heart being confined to the forward part of the body cavity and separated from the other internal organs by a muscular partition, the **diaphragm**, which aids in the expulsion of air from the lungs.

Most Mammals have their bodies covered with **hair** consisting of horny outgrowths from the skin. When very fine this covering of hair is known as **fur**, and as in many Birds there are down feathers underneath the others, so in fur-bearing animals there is often a short under-fur. Sealskin, as we know it, is the under-fur of certain types of Seal, the long coarse hairs having been removed by paring away the deeper layers of the skin so that those hairs, which are more deeply seated, simply fall out. Whales and Porpoises are absolutely without hair, while the Elephant and the Rhinoceros have very little. The function of hair is to preserve an equable temperature, this result being obtained in the case of the Whale and Porpoise by a layer of fat or blubber under the skin.

The **senses** in Mammals show a high stage of development, the sight of the Lynx, the powers of hearing and of scent possessed by the Deer, being proverbial. In many animals life depends upon the degree of efficiency of these senses which may provide warning of the proximity of enemies or of the approach of suitable prey. Equally proverbial is the blindness of the Bat and of the Mole, animals whose habits, nocturnal and subterranean respectively, make sight a matter of secondary consideration. In these cases the eyes are much reduced, while other senses, such as hearing and touch, show exceptional acuteness.

Classification of Mammals.—Primarily Mammals may be divided into three groups:

(*a*) Those which lay eggs, *e.g.* the Duckmole (*Ornithorhynchus*) and the Spiny Ant-eater, both of which are Australian.

(*b*) Those whose young are born incompletely developed, the remaining stages being completed in an external pouch or *marsupium* in which they are protected and nourished for some time. These are the **Marsupials**, a group which includes the Kangaroo. With the exception of the American Opossum, Marsupials are confined to the Australian region.

(*c*) All other Mammals. Here the unborn young are in intimate connection with the mother by means of the *placenta*, a spongy tissue which is well supplied with blood-vessels by means of which the embryo is nourished. These **Placentals** or **Higher Mammals** are subdivided into the following main groups:—

1. *Hoofed Animals*—(*a*) Even-toed, *e.g.* Pig, Camel, Ox, Sheep, Deer, Hippopotamus; (*b*) Odd-toed, *e.g.* Horse, Elephant, Rhinoceros.
2. *Aquatic Mammals*, *e.g.* Whales, Dolphins, Porpoises.
3. *Rodents* or *Gnawing Animals*, *e.g.* Rabbit, Hare, Guinea-Pig, Squirrel, Beaver, Rat, Mouse.
4. *Carnivorous Animals*, *e.g.* Lion, Tiger, Cat, Dog, Bear, Badger, Weasel; also the Seal, Sea-Lion, Walrus.
5. *Insectivorous Animals*, *e.g.* Hedgehog, Mole, Shrew, Bat.
6. *Primates*, *e.g.* Lemurs, Monkeys, Baboons, Apes, Man.

Any description of individual types amongst Mammals is beyond the scope of the present volume, and such descriptions are to be found in plenty in many books, but it is hoped that the present outline of animal life will enable students to appreciate the origin and significance of the many differences which occur amongst the Higher Animals and the definite relation which exists between the structure and the function of any organ. No lesson on any of these animals can be satisfactory which does not involve some consideration of the great principles of Evolution and of the various ways in which the animal in question is fitted by the dual influence of Heredity and Environment to secure a satisfactory food supply, to avoid the dangers of enemies, and to care for its young ones until their development and education are so far advanced as to make them independent of parental protection.

CHAPTER XI

EVOLUTION, VARIATION AND HEREDITY

Historical. — Just as in the fifteenth and sixteenth centuries there was a Revival of Learning which had a profound effect on Literature, so in the middle of the seventeenth century there began a great Renaissance in the study of Science, in which subject little real advance had been made since the time of **Aristotle** (384-322 B.C.). He collected a vast amount of information biological and medical, much of it, considering the difficulty of the subject and the ignorance of his age, wonderfully accurate. In Rome about A.D. 170 **Galen** became famous as a medical biologist and his writings formed the standard text-book of medical science for many centuries. In 1628 **Harvey** discovered the Circulation of the Blood and studied the development of the Chick. Soon after his time the compound microscope came into general use and discoveries began to be made which, before its invention, were impossible. For example, the sperms of animals were discovered, though little was known of their function. By some they were held to be the young animals which merely required the nutriment provided by the egg to develop into adults like their parents, while others looked upon them as parasites in the fertilising fluid, with no generative function at all. It was not till 1843 that **Martin Barry**, an Edinburgh medical student, observed the fertilisation of a rabbit ovum by the entrance of a sperm.

By 1700 **John Ray**, an English clergyman, had completed his system of classification of animals, and in 1707 was born in Sweden the great **Linnaeus**, who devised the system of classification which, with modifications, is the plan in use to-day in Botany and Zoology.

In France **Buffon** (1708-1788) and **Cuvier** (1769-1832) began to inquire into the "story of the rocks" as displayed by fossils. Both, however, believed with Linnaeus that there were "as many different species as there were different forms created in the beginning by the Supreme Being," and, consequently, failed to interpret the story as we understand it to-day.

Evolution. — **Goethe** (1749-1832), the German poet, philosopher and scientist, **Erasmus Darwin** (1731-1802) in England, and **Lamarck** (1744-1829) in France, basing their ideas on the geological discoveries amongst fossils, began to consider the possibilities of modification of species, or, in other words, that living things were not always as they are now, but that an evolution has been in progress, and that therefore the "present is the child of the past." It was becoming clear that ancient forms of plant and animal life differed from existing species and that there was a more or less gradual transition to be followed in fossil forms, that existing animals could be arranged in a series of increasing complexity, and that members in widely separated groups had much in the way of common structure; for example, that the fore limbs of the Bird, the Reptile and the Mammal were modifications of one and the same series of bones, thus indicating inevitably a common descent.

Thus the facts of Evolution (they are now universally accepted as facts) were being discussed long before the publication in 1859 of **Charles Darwin**'s *Origin of Species*, a book which not only confirmed and added to the facts already known, but propounded a Theory of Evolution which made the world, much against its will be it said, see the impossibility of rejecting the facts, much as opinions might differ as to the factors which brought about this gradual evolutionary development.

Lamarck attempted to explain the gradual evolution of living things on the line of *inheritance of acquired characters*. If any animal organ be continually used in a certain way it becomes, during the lifetime of the animal, modified in some way which makes it more efficient for this particular action. Lamarck maintained that this acquired character would be to some extent transmitted to succeeding generations, *e.g.* the muscular arm of the blacksmith, the long neck of the Giraffe, the long legs of Wading Birds, all of which, according to this view, were the cumulative result of effort along a particular line. Thus the Giraffe, which developed the habit of feeding on foliage above the reach of other animals, by constant practice extended its reach, and its progeny were born with longer necks than its parents had started with. This carried on in successive generations, granted the transmission of such an acquired character, would account for the abnormal neck and leg development which we know. Darwin, whose theory appeared fifty years after that of Lamarck, while admitting the possibility of this as a partial explanation, developed his theory of *Natural Selection*, or, as Herbert Spencer called it, the *Survival of the Fittest*. Other investigators, *e.g.* Alfred Russel Wallace, who quite independently arrived at similar conclusions to those of Darwin, denied altogether this *Use Inheritance* of Lamarck, and the matter is still a subject of dispute, the general view to-day being that the use-and-disuse theory (the disappearance of organs, *e.g.* the hind limbs of the Whale, might be explained on these lines) has not been proved, and that, so far as can be seen, characters acquired during the lifetime of an organism, which are really modifications brought about by the stimulus of environment from without, are not transmitted to the next generation. As is well known, the tails of lambs are artificially shortened and, though this has gone on for a very long time, no appreciable difference can be discerned in the normal tail length. On the other hand, the skeletal tail of the Bird, though we believe that animal to be descended from long-tailed ancestors, is a mere vestige, and the problem is to discover the factors which have brought about such a modification.

Darwinism.—Darwin, after numerous experiments on plants and animals, came to the conclusion that, while in the main an organism is like its parents in virtue of the great principle of Heredity, it is never identical but shows distinct *variations*. Some of these variations made the organism more fitted to its environment and more able to compete with its fellows in the *struggle for existence*. The successful competitors would survive and have the best chance of leaving descendants, and of these only the ones possessed of characters which fitted them for the struggle would succeed. Thus, just as the plant cultivator and the animal breeder have produced various types of plants and animals by careful selection in the course of many generations, so there is a *Natural Selection* which operates through this struggle for existence. Darwin held that the accumulation of these small variations, acting over a long period of time, gave rise to new species. That the struggle is a real one is well illustrated by a consideration of the number of fruits on, say, an Ash-Tree, or of eggs in a Cod. As the numbers of plants and animals remain more or less stationary, there is a weeding-out process on a vast scale.

Amongst the contemporaries of Darwin who supported his theory were **Wallace**, **Herbert Spencer** and **Thomas Huxley**, and, in Germany, **Haeckel**. By some his theory was hailed as providing a complete explanation of all the facts, while, as time went on and investigations were carried out, it became obvious that other factors must be considered. But it may be readily admitted that the *Origin of Species* "is a book that has probably influenced human thought more than any other."

Post-Darwinian Biology.—Amongst the later opponents of the theory of transmission of acquired characters was **Weismann**, the German biologist, who published the results of his study of heredity in *The Germ-Plasm* (1893). From his researches into the nature of germ cells and the work of the nucleus as a carrier of hereditary characters, he came to the conclusion that no changes acquired by the body could have any effect on these germ cells, and that therefore inheritance of acquired characters was impossible. His belief is well summed up in his own phrase, "continuity of the germ-plasm." He held that these germ cells are set apart at a very early stage in the development of the embryo, and these, as we know, are produced by the continued division of the original fertilised egg cell. Hence the sexual or germ cells form a continuous series, the body of the organism being, in his view, a mere excrescence or offshoot of a temporary character, the container, as it were, of the germ cells. The latter, like *Amoeba*, go on for ever, dividing many times and, when opportunity occurs, conjugating. According to this view, a young organism inherits its particular characters from the germ cells, and not from the bodies, of its parents. Thus it has a heritage, derived mostly from its immediate parents, but partly from all its ancestors, the contribution of each previous generation being less and less as the ancestors become more remote. **Francis Galton** (a cousin of Charles Darwin) and, later, Professor **Karl Pearson**, from a study of certain selected characters in a great many organisms, through numerous generations, expressed these facts of inheritance quantitatively, in figures derived as the averages of many counts. Galton's *Law of Ancestral Inheritance*, as it is known, states that "the two parents contribute between them on the average half of the total heritage of the offspring, the four grandparents a quarter, the eight grandparents an eighth, and so on." Karl Pearson produced independently similar figures, the contribution of the parents being, according to him, a little higher.

Variation.—By variations Darwin meant the small differences which exist in all cases between offspring and parents, and, as we have seen, he believed that it was the accumulation of these variations that, under the influence of Natural Selection, produced new species.

Later scientists, notably **De Vries** and **Bateson**, considered these small variations insufficient, and drew attention to the larger differences which sometimes appear in "sports" or "freaks," and indicated that these *Mutations*, as they were called to distinguish them from the smaller variations, were of much commoner occurrence than was commonly supposed. These big jumps, they held, were much more likely to be the cause of new varieties, and they were able to show that in many cases these "sports" bred true, *i.e.* gave rise to offspring showing the same peculiarities. This, of course, seemed to show that the mutations were present also in the germ cells, having appeared there suddenly in some unexplained way.

Mendelism.—In 1865 the first of a series of papers was read before the Natural History Society, Brunn, in Austria, by **Gregor Mendel**, a priest, who was at first a teacher of natural science and later the abbot of his monastery. The communications gave the results of some experiments he had carried out mainly on the crossing of different kinds of peas. His duties as abbot apparently interrupted his researches, and nothing further was heard of the matter till about 1900, when three independent workers, **De Vries** in Holland, **Correns** in Germany and **Tschermak** in Austria, made similar discoveries, and the importance of Mendel's work came to be recognised. This was the starting-point of a new era in the investigation of the problems of heredity, and Mendel's work ranks amongst the great discoveries of science. "Mendelism" has become almost a household word, and the breeding of plants and animals is beginning to be carried out on much more scientific lines, though many successful producers have obtained wonderful results with little or no scientific knowledge—for example, Mr Burbank, the "Wizard of California," who has given us stoneless prunes, white blackberries, the "plumcot," and many other wonderful hybrids which bid fair to revolutionise the nature of our fruit supplies.

Mendel examined successive generations of peas with special regard to certain well-marked characters. Some peas, for example, were yellow, some green. On crossing a plant which produced yellow peas with one producing green, he found that all resulting peas were yellow, but that when these plants were interbred 75 per cent. produced yellow peas, while 25 per cent. produced green peas. The latter when interbred bred true and produced nothing but green peas, while of the others, a third (*i.e.* a fourth of the total number of this generation produced nothing but yellow peas, while the remainder behaved like those of the first generation, and produced both yellow and green. Here, then, are two pure strains (with regard to this particular colour character), the remainder being mixed, *i.e.* containing both yellow and green. This might be expressed diagrammatically as follows (Y = yellow, G = green):—

Original Plants Y × G
1st Generation Y (G) (all appear yellow)
2nd do. Y Y (G) Y (G) G

Such results point to there being in the germ cell separate units or factors for this character under consideration. If there were a blending of these units in the fertilised ovum then a greenish yellow colouring might be expected in the next generation, whereas the colours remain pure, yellow or green. But as some of the yellows in the first generation give rise to greens, green must be represented in the germ cells, its effect in the pea being masked or inhibited by the stronger or *dominant* yellow (green being *recessive*).

If we consider a number of germ cells each containing one of these characters Y and G, then obviously when conjugation of cells takes place

Y may fertilise Y, giving YY = yellow
Y ,, ,, G, ,, YG = appears yellow
G ,, ,, Y, ,, GY = ,, ,,
G ,, ,, G, ,, GG = green

and these are the proportions found in Mendel's experiments.

This discovery, perhaps not great in itself, has stimulated much subsequent investigation, and, though the whole question of heredity bristles with difficulties, much has been discovered which seems to promise an ultimate solution of these problems.

Such discoveries will doubtless have far-reaching effects on the future of cultivated plants and domestic animals, and the special branch of this science, *Eugenics*, may in time do much for the betterment of the human race.

This chapter can only be a brief and imperfect sketch of the whole subject, but it is hoped that it may stimulate further study in the larger text-books, or, at least, help towards a more intelligent appreciation of the many articles which throng the public Press.

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APPENDIX

SOME USEFUL BOOKS

The Harmsworth Encyclopædia.

Thomson, J. Arthur: *Outlines of Zoology* (Henry Frowde).

Lulham: *Introduction to Zoology* (*Invertebrates*) (Macmillan).

Parker and Haswell: *Text Book of Zoology* (2 vols.) (Macmillan).

Burlend: *First Book of Zoology* (Macmillan).

Newbigin: *Life by the Seashore* (Swan Sonnenschein).

Furneaux: *The Sea Shore* (Longmans Green).

Farmer: *Book of Nature Study* (Caxton).

Sedgwick: *The British Nature Book* (Jack).

Thomson, J. Arthur: *Study of Animal Life* (John Murray).

Gamble: *The Animal World* (Home University Library).

Lock: *Variation, Heredity and Evolution* (John Murray).

Dendy: *Outlines of Evolutionary Biology* (Constable).

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